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Aircraft Emissions at Selected Airports, 1972-1985

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Aircraft Emissions at Selected Airports 1972-1985

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Standards Development and Support Branch
Emission Control Technology Division
Office of Air and Waste Management
U.S. Environmental Protection Agency

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Abstract

This report presents airport vicinity aircraft emissions data for HC, CO and NOx at selected commercial and general aviation airports. The data represents an updating of calculated aircraft emissions for recent years and estimates of future aircraft emissions. Operations by individual aircraft models are scrutinized in detail. Breakdowns of operations by air carriers, air taxis, general aviation and auxiliary power units are included and the emissions from each are summed to provide estimates of total pollutants dispersed. Despite a general trend toward more operations, the total emissions at the commercial airports decrease as a result of a changing fleet mix with more modern engines and the advent of promulgated and proposed regulatory standards. With increased operations at general aviation airports, emissions will continue to increase without the imposition of regulatory standards because uncontrolled modern engines emit substantially the same pollutants as older piston engine designs.

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16. ABSTRACT

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Introduction

This report presents airport vicinity aircraft emissions data for HC, CO and NOx. The data represents an updating of calculated aircraft emissions for recent years and estimates of future aircraft emissions at several selected commercial and general aviation airports. This report does not provide comparisons with non-aircraft emissions sources nor establish the significance of the emissions dispersed by aircraft in the airport vicinity, but rather provides updated data for follow-on reports that analyze the significance of the aircraft burden and make suitable comparison with land born sources.

Detailed estimates of the future aircraft emissions burden in the vicinity of airports are needed to support final rulemaking in the 1983 retrofit program for T2 class engines over 29,000 lbs. thrust (NPRM, 38 FR 19050; Tuesday, July 17, 1973) and for possible amendment of current rules for subsonic aircraft (38 FR 19087; Tuesday July 17, 1973).

Previous studies have attempted to develop a satisfactory methodology for assessing the aircraft emissions impact and have gathered data by physical measurement at sites in the vicinity of selected airports. The methodology studies include the EPA-Argonne National Laboratories Pollution Impact Methodology Report[1] and the GCA/Technology Division Airport Emission Inventory Methodology Report[2].

The EPA-Argonne Methodology Report addresses a selected airport and its environs as an aggregate source of air pollution. The methodology presented integrates the air pollution impact of an airport and its associated ground support with that of the urban development in its vicinity. A quantitative basis for decisions related to airport site selection and the development of surrounding land is provided. The GCA/Technology Report presents a methodology for performing emission inventories at airports including submethodologies for municipal, military and civilian airports. The methodology is directed to obtaining emissions data from both aircraft and surface sources at all airports within a metropolitan region and combining the data to provide an indication of the airport burden upon the air quality control region (AQCR).

Both methodology studies include data from actual airports and environments to illustrate the applicability and limitations of the methodologies. Conversely, some of the data gathering studies below include methodologies utilized to obtain and assimilate the data into meaningful form.

A third study, the Northern Research and Engineering Report[3], is limited to the presentation of calculated percentages separately indicating the contribution of aircraft and airport emissions to national and regional total emissions. The regional impacts are presented for selected cities and airports therein.

The EPA report[4], published in accordance with Section 231(a) of the Clean Air Act as amended, presents a compilation of the available information on the present and predicted air pollution related to aircraft operations in the United States.

The LAPCD report[5] investigated the emissions impact of turbine engine aircraft operation in the vicinity of Los Angeles International Airport in 1969 and 1970. The report objectives included determination of pollutant emissions from aircraft and ground operations, the measurement of atmospheric pollutant concentrations at ground level and the determination of CO exposure in an aircraft cabin during ground operations.

The Celesco Industries report[6] contains the supporting raw data and technical measurement information prepared for the Airport Vicinity Air Pollution Study[7] by Argonne National Laboratories for the Federal Aviation Administration. Celesco obtained airborne and ground level data at O'Hare International Airport (ORD) and Orange County Airport (SNA). The Argonne-FAA Report presents the development of a mathematical model for estimating the emissions from the airport and environs and computing the resultant pollutant concentrations at preselected sites in the airport vicinity. The model is tested against the measured data at O'Hare and Orange County Airports.

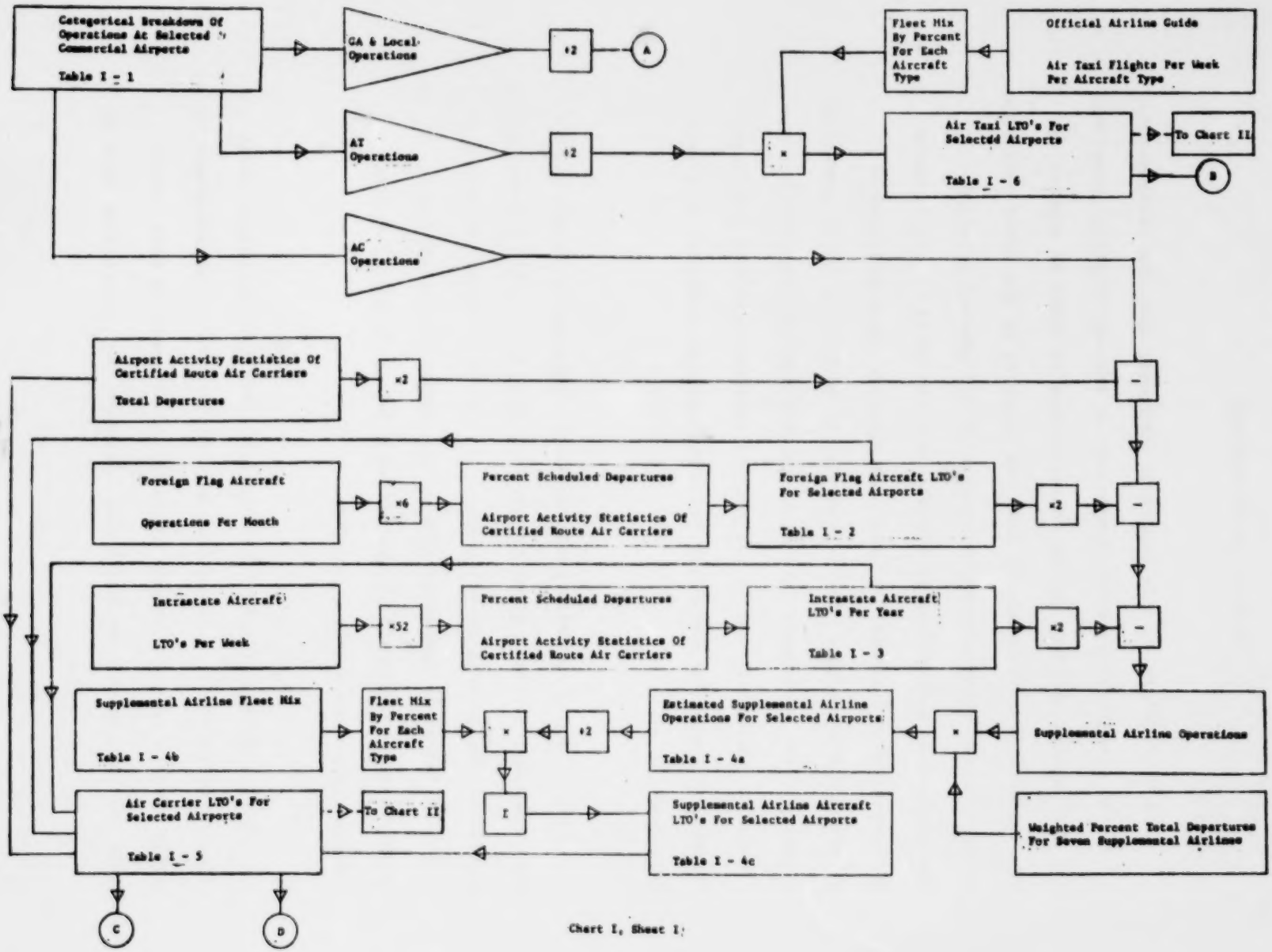
Unfortunately, the predictions of the mathematical models and methodologies developed above have had certain weaknesses. Such studies have not adequately taken into account the fleet mix differences between seemingly similar commercial airports. The fleet mix utilizing a particular airport is dependent upon the particular airlines servicing the airport, the airport physical plant (runway length, etc.) and location. The fleet mix can have a decided effect upon the length of time before older and dirtier aircraft are phased out to the point where their effect on overall emissions at the airport become inconsequential.

Summary of Methodology

The methodology of this report is dependent upon the predominance of either commercial aviation operations or general aviation operations. The ten busiest airports in the United States in terms of numbers of operations fall overwhelmingly into one category or the other with none evenly divided between commercial aviation and general aviation. Therefore, the methodology is divided into two parts, i.e., airports representative of commercial usage and airports representative of general aviation usage. The methodology is applied to three commercial airports (John F. Kennedy International, Los Angeles International and O'Hare International) and to six general aviation airports (Van Nuys, Tamiami, Phoenix, Fairbanks and San Jose Municipal combined with Reid Hillview).

Part I of the Appendix presents the methodology in detail for the commercial aviation airports and Part II presents the methodology in detail for the general aviation airports. Block diagrams presented in Charts I through IV summarize briefly the computational approach. As is apparent from the block diagrams the methodology is dependent upon compiled resources available to EPA.

Chart I depicts the step-by-step procedure for estimating total aircraft emissions at a commercial airport for 1972. The procedure is easily adapted to calculations for more recent years as more recent input information becomes available. Intermediate information such as



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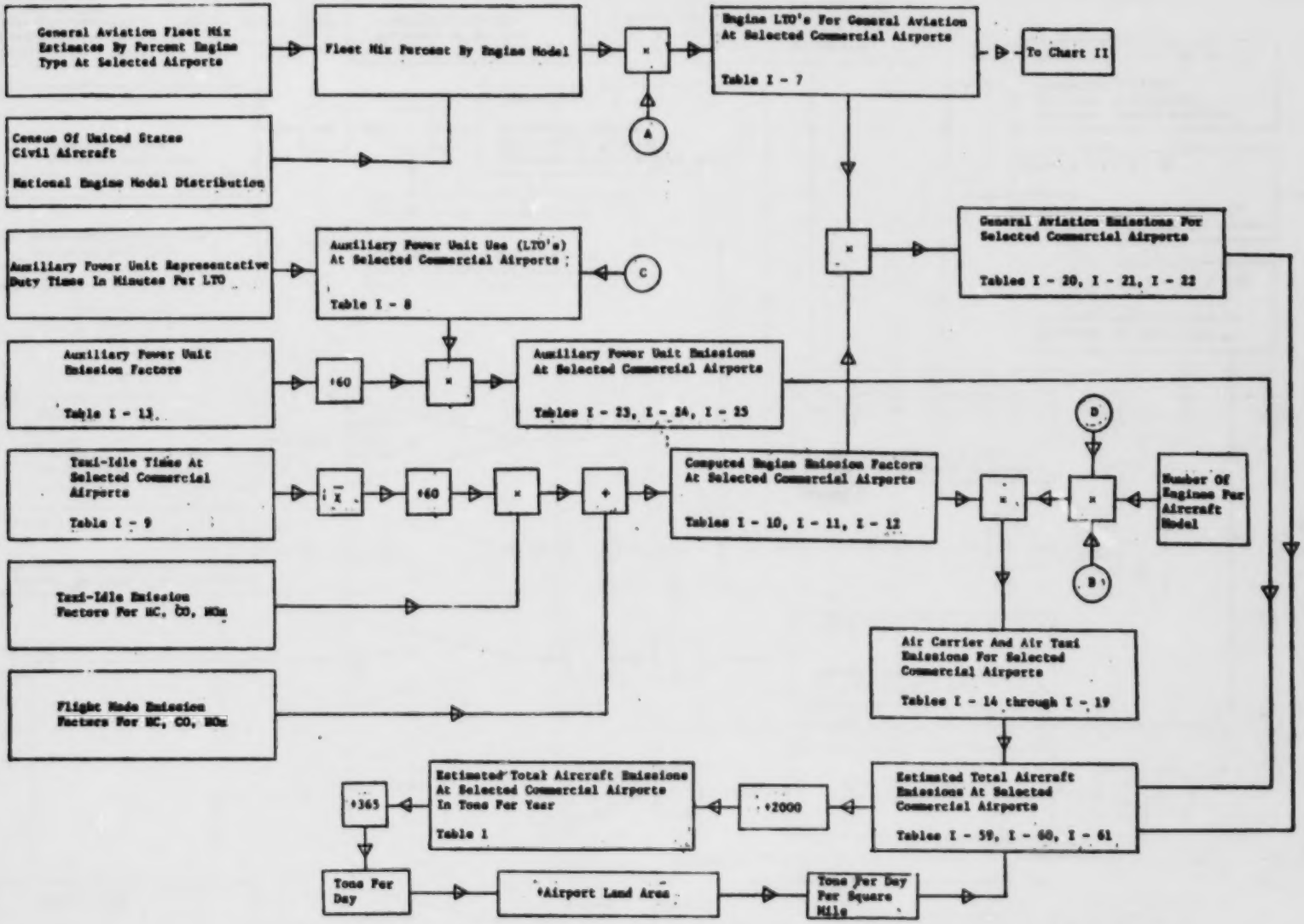
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Tons Per Day Per Square Mile
A
B
C
D

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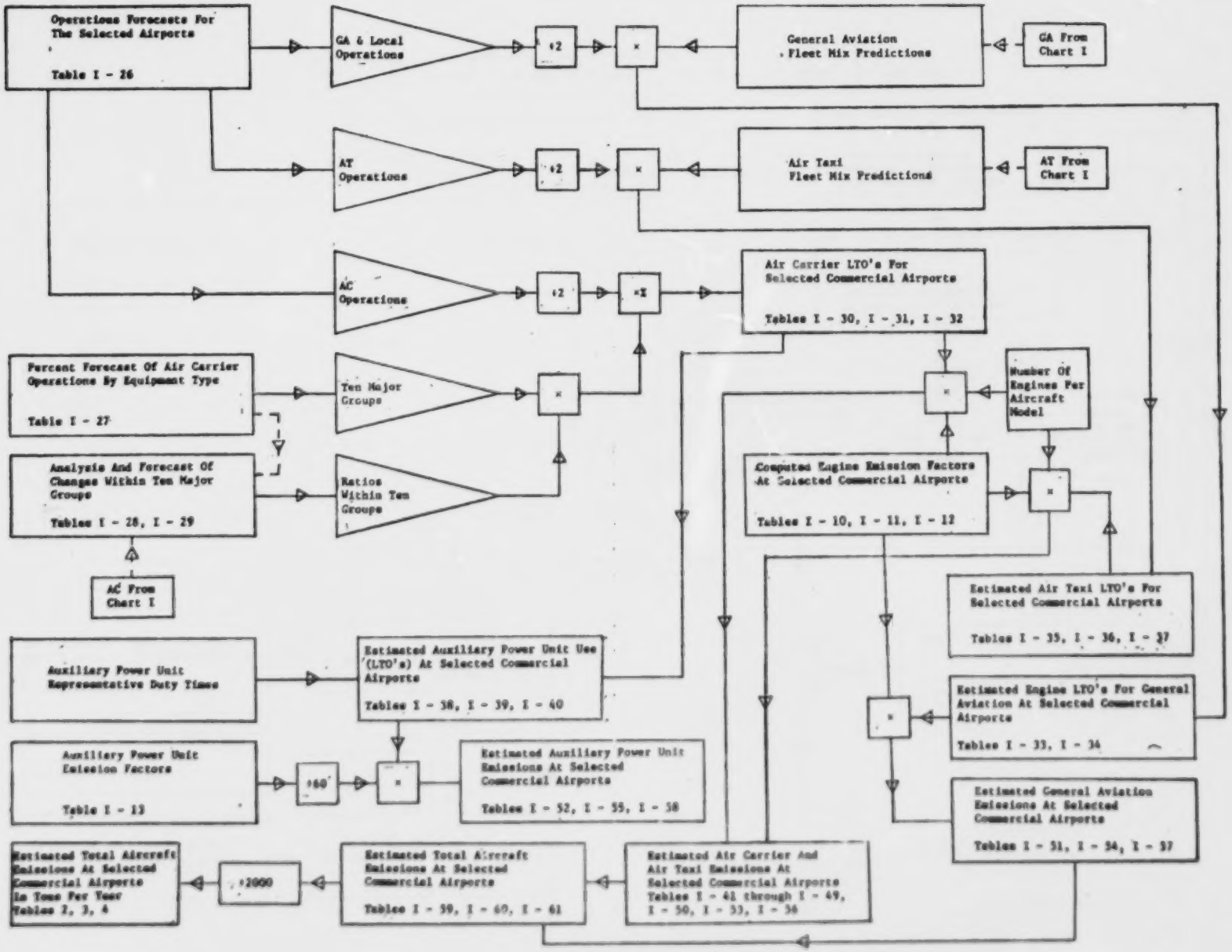
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Chart II

numbers of landing and take-off cycles (LTOs) for a specific aircraft type at a specific airport are easily accessible. The procedure of Chart I is also applicable to estimating emissions at airports that have substantial general aviation operations or are evenly divided between commercial and general aviation with the limitation that the estimates of the general aviation fleet mix at the particular airport selected must be reasonably accurate.

Chart II depicts the procedure for estimating total future air craft emissions at a commercial airport. The procedure is dependent upon the analysis of current trends in aircraft production and design and, expectations of future commercial aircraft usage. Predictions of future air carrier usage at the twenty-five busiest commercial aviation airports in the Untied States are available, however, predictions of air taxi and general aviation operations at commercial airports are either unavailable or conflicting. It is commonly assumed that general aviation operations will become negligible or eliminated at the nation's busiest commercial airports yet at least one FAA report[8] implies a substantial increase at John F. Kennedy International in the 1980's. It is also expected that air taxi usage will increase, however, the increasing passenger load may be taken up by higher load factors and larger used aircraft purchased from the certified route air carriers rather than by new replacement aircraft similar to the current fleet aircraft. There is also the increasing use of helicopters for air taxi purposes.

In utilizing the procedure of Chart II to estimate future emissions at a selected commercial airport, the airport must be analyzed in accordance with the procedure of Chart I for a recent year at least to the point where LTOs per aircraft type for air carriers, air taxis, general aviation and auxiliary power units are known. Note that this procedure includes auxiliary power unit usage as a time period per LTO. Estimates for 1972, 1975, 1980 and 1985 are included in this report for the three commercial airports above.

Chart III depicts the procedure for estimating aircraft emissions at a predominately general aviation airport in 1974. The procedure assumes that commercial aviation and military operations are negligible as well as non-piston engine air taxi and general aviation. The procedure assumes the breakdown of operations by aircraft type for a selected airport coincides with the breakdown of active general aviation aircraft in the surrounding county. On this basis, for the general aviation airports studied, the deletion of non-piston engine air taxi and general aviation aircraft is deemed reasonable. Where inclusion is required the procedure of Chart I may be applied. Piston powered air taxi operations can be included as part of the general aviation operations when aircraft type information is available.

The LTOs are presented in terms of number of engines and model. Emissions data are unavailable for many of the piston engine models. In these cases an engine of similar horsepower for which data is available is substituted.

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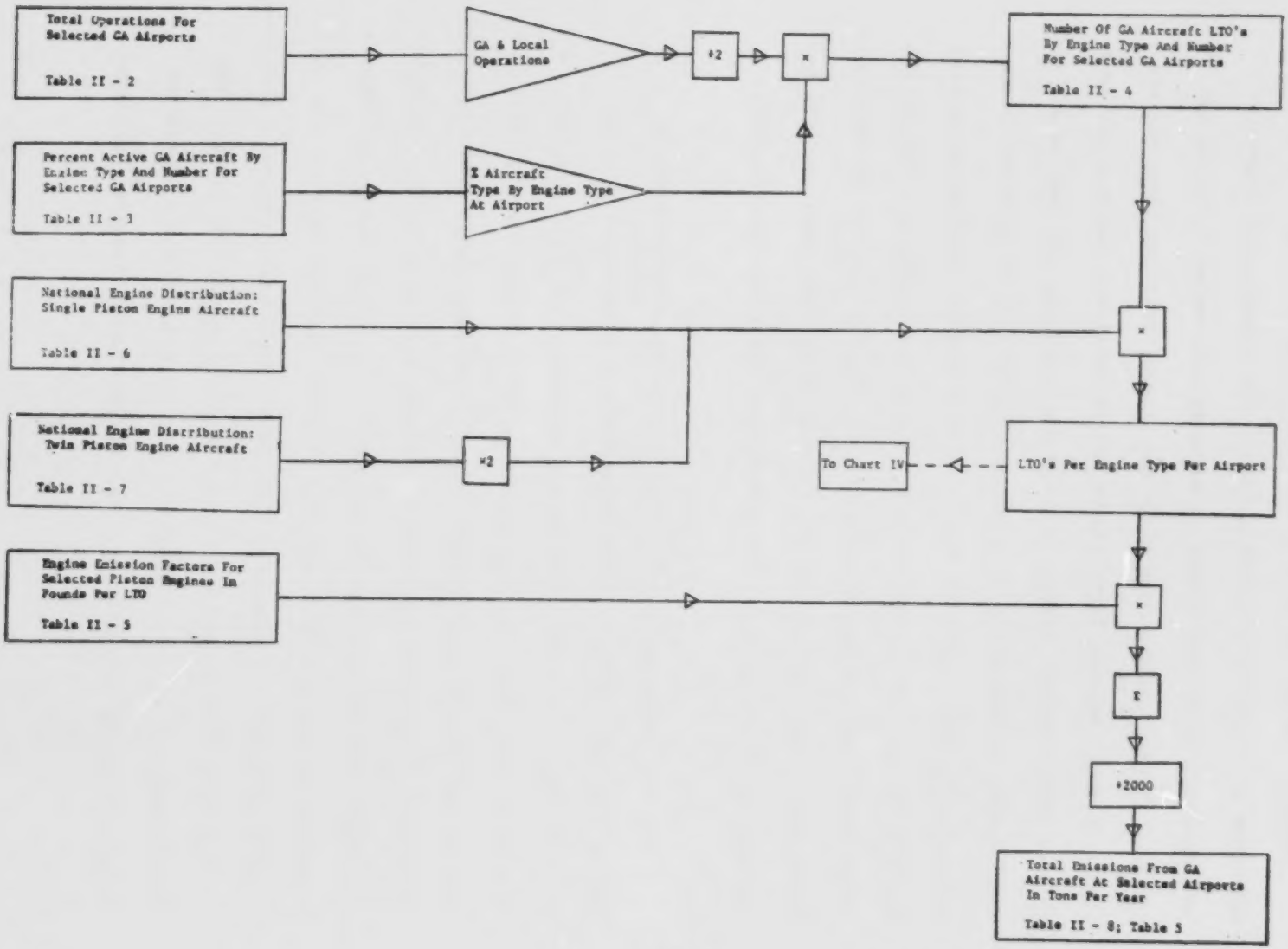
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Σ Aircraft Type By Engine Type At Airport
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÷2000
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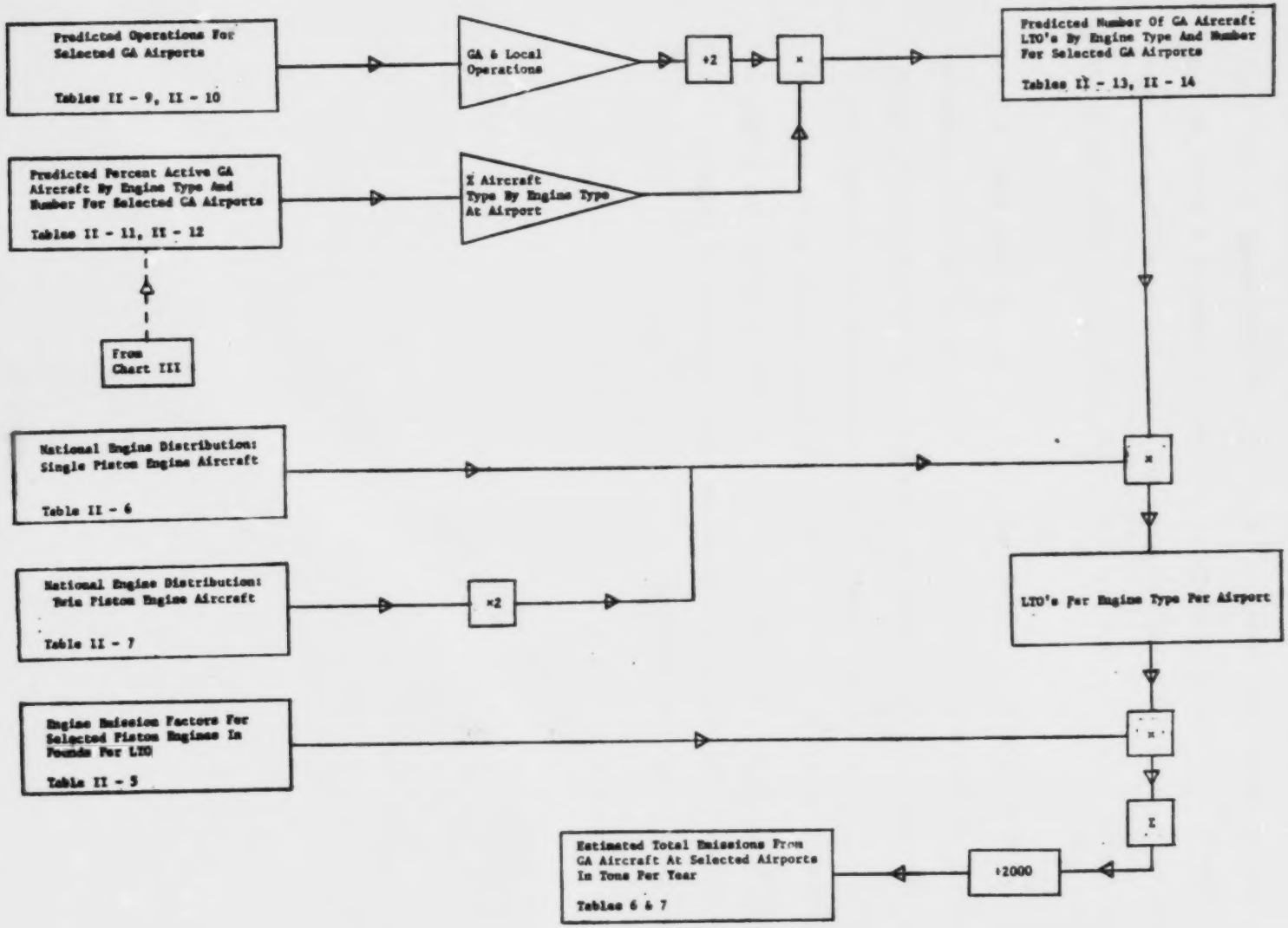
CHART III

Chart IV depicts the procedure for estimating total future aircraft emissions at a general aviation airport. The procedure is dependent upon analysis of current trends in business and executive flying and in pleasure flying. Sudden changes in the general aviation fleet mix are highly unlikely because light planes for personal and business use have 20 year useful lives. Trends in fleet mix therefore are long term. The total number of operations at a selected airport to be expected in the future is the more important factor. The procedure requires an initial analysis in accordance with Chart III for a recent year at least to the point where LTOs per engine model for the selected airport are available. Estimates of total HC, CO and NOx for the years 1974, 1980 and 1985 are included in this report for the six general aviation airports above.

The most important data sources for the procedures shown in Charts I-IV are supplied by the Department of Transportation, the aircraft engine manufacturers and the publishers of airline guides. The Airport Activity Statistics of Certified Route Air Carriers[9], published yearly, and the Official Airline Guide[10], published twice monthly furnish departures or arrivals in terms of aircraft type or model for scheduled airlines. The FAA Air Traffic Activity[11], published yearly, provides a breakdown of operations at specific airports into air carrier, air taxi, general aviation and military. The FAA-Terminal Area Forecast[8], published in September 1974 presents estimates of total operations through 1986 broken down for air carrier and air taxi with the balance considered general aviation and military. The FAA Equipment Forecast[12] provides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÷2
×
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National Engine Distribution: Twin Piston Engine Aircraft
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×2
×
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Engine Emission Factors For Selected Piston Engines In Pounds Per LTO
Table II - 5
×
Σ
÷2000
Estimated Total Emissions From GA Aircraft At Selected Airports In Tons Per Year
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CHART IV

percentage breakdown of the future operations for ten principal aircraft types at twenty-five commercial airports. The FAA Census of U.S. Civil Aircraft[13] provides breakdowns of aircraft by number of engines and type for each county and by manufacturer and number active nationwide. Most emissions factor data was provided to EPA directly by engine manufacturers.

The methodology of this report does not provide breakdowns of pollutants dispersed as a function of time of day or location within or without the selected airport environs but rather provides estimates of yearly total pollutant dispersed and breakdowns of the pollutant contribution of specific aircraft models or engine models at the selected airports. Thus, the procedure can only be used to assess the effect of alternative regulatory actions on the total emissions by class of aircraft at selected airports.

Discussion of Calculated Results for Selected Airports

Tables 1 through 4 summarize calculated estimates of the three pollutants HC, CO, and NOx dispersed from aircraft at the three predominately commercial aviation airports selected for study, namely John F. Kennedy International (JFK), Los Angeles International (LAX) and O'Hare International (ORD). 1972 constitutes a baseline summation of pollutants dispersed as a result of aircraft activity.

It is immediately apparent from Tables 1 through 4 that the contribution by air carrier (AC) operations constitutes the overwhelming bulk of the pollutants dispersed. Virtually all AC operations are performed by aircraft with engines in the T2, T3, and T4 classes. The exceptions are principally Lockheed Electras and Hercules turboprops. The Electras are expected to be phased out before 1980 by obsolescence.

Aside from helicopters, the air taxi (AT) fleets are mostly small jet and turboprop aircraft with engines in the T1 and P2 classes. The general aviation (GA) fleets operating from commercial airports are also mostly small jet and turboprop aircraft because of the relatively high landing speeds required at the busiest commercial airports.

The decrease in total pollutants from 1972 to 1975 is generally attributable to a combination of decreased aircraft operations and the changing fleet mix of air carriers. The further substantial decreases

Table 1

Estimated Total Aircraft Emissions at Selected Commercial Airports for 1972 in T/yr

	JFK			LAX			ORD		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
AC *(T2, T3, T4)	10,559 99.35%	15,117 96.26%	2,843 91.9%	7,396 97.39%	11,564 92.18%	2,969 90.84%	8,699 99.59%	15,082 94.09%	4,006 92.19%
AT (T1, P2)	18 0.17%	52 0.33%	3 0.08%	33 0.43%	47 0.37%	7 0.2%	69 0.78%	91 0.56%	11 0.24%
GA (T1, P2, P1)	41 0.39%	207 1.32%	10 0.32%	157 2.07%	635 5.06%	54 1.63%	45 0.51%	494 3.08%	10 0.23%
APU	10 0.09%	329 2.09%	238 7.7%	9 0.11%	300 2.39%	240 7.33%	11 0.12%	364 2.27%	319 7.34%

* Aircraft engines overwhelmingly of classes noted.

Table 2

Estimated Total Aircraft Emissions at Selected Commercial Airports for 1975 in T/yr

	JFK			LAX			ORD		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
AC *(T2, T3, T4)	9,082 99.35%	14,513 95.98%	3,141 90.7%	5,739 96.89%	10,243 91.65%	3,349 89.38%	6,799 97.82%	13,876 93.61%	4,562 90.99%
AT (T1, P2)	20 0.22%	54 0.36%	3 0.07%	37 0.62%	53 0.47%	7 0.19%	91 1.31%	98 0.66%	14 0.28%
GA (T1, P2, P1)	26 0.28%	161 1.06%	5 0.15%	133 2.25%	538 4.81%	45 1.2%	45 0.65%	432 2.91%	9 0.18%
APU	14 0.15%	394 2.6%	315 9.08%	15 0.24%	343 3.07%	346 9.23%	16 0.22%	418 2.82%	429 8.55%

* Aircraft engines overwhelmingly of classes noted.

Table 3

Estimated Total Aircraft Emissions at Selected Commercial Airports for 1980 in T/yr

	JFK			LAX			ORD		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
AC *(T2, T3, T4)	5,322 99.2%	12,080 95.23%	3,913 89.61%	3,761 97.59%	9,142 93.35%	4,282 89.29%	4,634 97.01%	13,003 94.7%	5,655 89.84%
AT (T1, P2)	22 0.41%	65 0.51%	3 0.07%	46 1.19%	65 0.66%	8 0.17%	120 2.5%	158 1.15%	19 0.29%
GA (T1, P2, P1)	- -	- -	- -	25 0.65%	102 1.04%	9 0.18%	- -	- -	- -
APU	21 0.39%	540 4.26%	451 10.32%	22 0.57%	485 4.95%	497 10.36%	24 0.49%	570 4.15%	621 9.87%
Total AQCR Emissions	824,000	2,453,000	-	817,000	2,020,000	-	789,000	1,311,000	-
% Aircraft (at selected airport)	0.65%	0.52%	-	0.47%	0.48%	-	0.61%	1.05%	-

* Aircraft engines overwhelmingly of classes noted.

Table 4

Estimated Total Aircraft Emissions at Selected Commercial Airports for 1985 in T/yr

	JFK			LAX			ORD		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
AC *(T2, T3, T4)	2,695 95.3%	7,566 91.39%	3,119 85.26%	1,689 95.64%	5,495 89.39%	3,239 84.6%	2,247 93.7%	8,439 90.96%	4,523 83.35%
AT (T1, P2)	21 0.75%	71 0.85%	4 0.11%	49 2.75%	78 1.26%	12 0.31%	123 5.13%	176 1.89%	26 0.49%
GA (T1, P2, P1)	- -	- -	- -	3 0.17%	12 0.18%	1 0.03%	- -	- -	- -
APU	26 0.95%	643 7.76%	535 14.63%	26 1.44%	564 9.17%	577 15.06%	28 1.17%	663 7.15%	690 13.16%
Total AQCR Emissions	540,000	1,244,000	-	681,000	1,061,000	-	803,000	778,000	-
% Aircraft (at selected airport)	0.51%	0.67%	-	0.26%	0.58%	-	0.30%	1.19%	-

* Aircraft engines overwhelmingly of classes noted.

can be attributed to changes in fleet mix by 1980 and the additional effect of the phase in of aircraft subject to the currently mandated controls and the proposed retrofit program. The total number of operations are predicted to substantially increase in future years. The change in fleet mix by 1980 is substantially the continuing replacement of older narrow body jet carriers by newer wide body jets with improved control over HC and CO emissions. Under the proposed retrofit program 12.5% of the wide body jets are assumed retrofitted by 1980 and all wide body jets are assumed either retrofitted or new by 1985. Partly as a spinoff from the smoke retrofit programs for T3 and T4 class engines some older aircraft also contribute to lower HC and CO emissions in the future despite increased operations.

Although by 1985 a substantial number of auxiliary power units (APU) are expected to meet the promulgated standards, the total APU emissions increase throughout the 1972-1985 period of this study. The changing fleet mix of air carrier aircraft includes increasing numbers of aircraft with APUs. New commercial aircraft are commonly equipped with APUs whereas, many older commercial aircraft comprising a large portion of today's fleet are not so equipped. It may be noted here that the increasing use of APUs lessens the need for ground based starting units.

Air taxi (AT) total emissions are predicted to increase throughout the 1972-1985 period of the study. The study assumes that the current AT aircraft models used at each airport will continue to be used in the future and not replaced by different models. A 25% replacement

by 1985 with new aircraft of the same size but meeting promulgated standards is assumed for most of the AT fleet. It is likely that such will not be the case, however, because increases in passenger demand and fuel costs create a tendency toward higher load factors and larger aircraft. Thus, the AT fleet mix is likely to change with the intro duction of new planes and used planes purchased from ACs both with increased capacity. Unfortunately, no quantitative predictions of the future AT fleet mixes were obtained.

General aviation (GA) total emissions taper off to negligible amounts at the commercial aviation airports studied. JFK and ORD landing speed requirements already limit GA operations to turbine powered and large twin piston engine aircraft, thus effectively eliminating local and pleasure operations by light piston engine aircraft. The GA is predominately business and executive flying at JFK and ORD. A similar trend is evident at LAX, however, the landing speed requirements are not as stringent and there is a little used but operational runway for GA at LAX.

Tables 5, 6 and 7 summarize calculated estimates of the three pollutants HC, CO and NOx dispersed from aircraft at six predominately GA airports selected for study. Van Nuys (VNY), located in the Los Angeles basin, was third in total operations and first in GA operations in the U.S. in 1974. Phoenix Sky Harbor (PHX) and Tamiami (TMB) are located in hot sunny urban environments. Fairbanks International (FAI) has extremely high GA activity for the community size and severe temperature inversions.

Table 5

CY 1974 Summary of Total Emissions
From GA Aircraft at Selected Airports in T/yr

Airport	% of Total LTOs	HC	CO	NOx
Van Nuys (VNY)	91.6	56	2488	10
Tamiami (TMB)	91.0	35	1551	6
Phoenix (PHX)*	71.0	33	1448	6
Fairbanks (FAI)**	86.4	14	631	3
San Jose Municipal (SJC) San Jose Reid HV (RHV)]	89.4	64	2827	12

* Includes piston engine AT
**Includes all AT as twin piston engine

Table 6

FY 1980 Predicted Total Emissions From GA Aircraft at Selected Airports in T/yr

Airport	% of Total LTOs	HC	CO	NOx	Total AQCR Emissions HC	*% Aircraft	CO	% Aircraft
Van Nuys (VNY)	91.0	74	3306	13	817,000	0.009	2,020,000	0.16
Tamiami (TMB)	92.7	55	2429	9	-	-	-	-
Phoenix (PHX)	72.6	44	1937	8	186,000	0.02	376,000	0.52
Fairbanks (FAI)	89.7	25	1128	4	-	-	-	-
San Jose Municipal (SJC) San Jose Reid HV (RHV)	89.6	84	3763	15	501,000	0.02	1,003,000	0.38

* At selected airport.

Table 7

FY 1985 Predicted Total Emissions From GA Aircraft at Selected Airports in T/yr

Airport	% of Total LTOs	HC	CO	NOx	Total AQCR Emissions HC	*% Aircraft	CO	% Aircraft
Van Nuys (VNY)	91.0	83	3714	15	681,000	0.01	1,061,000	0.35
Tamiami (TMB)	92.8	78	3455	13	-	-	-	-
Phoenix (PHX)	73.0	50	2199	9	186,000	0.03	219,000	1.00
Fairbanks (FAI)	89.4	31	1377	5	-	-	-	-
San Jose Minicipal (SJC) San Jose Reid HV (RHV)	89.3	94	4212	17	435,000	0.02	560,000	0.75

* At selected airport.

San Jose Municipal (SJC) and San Jose Reid Hillview (RHV) are located within the environs of the city and combined for a city wide sample. The operations at these airports are overwhelmingly by piston engine aircraft and as a result the emissions are predominately CO. A worst case of no standards for GA piston engine is assumed for the 1974-1985 period. The CO emissions increase with the increase of GA operations. In two cases (TMB and FAI) the CO emissions can be expected to double.

Appendix

Methodology for Computation of Aircraft Emissions

The methodology is dependent upon the predominance of either commercial aviation operations or general aviation operations. Therefore, the methodology is divided into two parts, i.e., airports representative of heavy commercial usage and airports of heavy general aviation usage. The commercial airports selected are located in highly urban communities. The general aviation airports selected are located in highly urban communities or communities with atmospheric conditions that emphasize the effect of airborne pollutants.

The methodology of Part I of this Appendix is applied to commercial airports and the methodology of Part II is applied to general aviation airports. The following definitions apply to this study:

Definitions:

Air Carrier (AC) - All CAB Certified Route Air Carriers plus supplemental, foreign-flag and intra-state commercial air carriers. This category does not include Air Taxi (commuter air carriers), Military or General Aviation flights.

Air Taxi (AT) - Air Taxi and commuter air carrier operation carrying passengers, mail or cargo for revenue in accordance with FAR Part 135 or Part 121.

Certificated Route Air Carriers - Air carriers holding a Certificate of Public Convenience and Necessity issued by the CAB to conduct scheduled services over specified routes. Certain nonscheduled or charter operations may also be conducted by these carriers.

Commuter Air Carriers - See Air Taxi.

Foreign-Flag Air Carriers (FF) - Commercial Air Carriers who do not maintain the United States as the country in which ownership is located. They do not file reports with CAB on airport activity but do generally file with the International Civil Aviation Organization (ICAO).

General Aviation (GA) - All aircraft activities not performed by Air Carrier, Air Taxi, or Military aircraft.

Intra-State Air Carriers (I-S) - Air Carriers not required to certify with the CAB but with scheduled routes primarily within a particular state and primarily into one major airport. The study only uses this category for those flights actually labelled Intra-State in the Official Airline Guide[10].

Itinerant Operations - Those aircraft operations which originate from or are destined for another airport.

LTO Cycle - A cycle including both a landing and a takeoff of an airplane. An LTO is equivalent to two aircraft operations or one departure and one arrival.

Local Operation - Operations performed by aircraft which:

a) Operate in the local traffic pattern or within sight of the tower.

b) Are known to be departing for, or arriving from, flight in local practice areas located within a 20-mile radius of the control tower.

c) Execute simulated instrument approaches or low passes at the airport.

Operation - An aircraft arrival at or departure from an airport with FAA airport traffic control serivce. There are two types of operations - local and itinerant.

Supplemental Air Carriers (SUP) - Air Carriers which possess Certificates of Public Convenience and Necessity issued by the CAB for the performance of planeload air freight and passenger charters throughout the U.S. and most overseas countries. They are unscheduled operators. U.S. Supplemental AC's are affiliated with the National Air Carrier Association (NACA).

Part I

Methodology for Computation of Aircraft Emissions at Airports with High Levels of Commercial Usage

Los Angeles Internationl Airport (LAX), Chicago O'Hare Field (ORD) and John F. Kennedy International Airport (JFK), New York were selected as airports representative of heavy commercial usage at present and to be expected in the future. The overwhelming number of operations per year are by aircraft of Civil Aeronautics Board (CAB) Certificated Route Air Carriers.[8,9,11]

Categorical Breakdown of Operations at Selected Airports

The initial source of statistics for the number of operations at the selected airports is Table 4 of the FAA Air Traffic Activity[11] (ATA) for Calendar Year 1972. This table lists the categorical total operations of Military, General Aviation (GA), Air Taxi (AT) and Air Carrier (AC). As shown below a breakdown by aircraft type is developed within each of the categories, except Military. The Military constitutes 1.5% or less of the operations at the airports selected and is discarded as beyond the scope of this study since no Military Aircraft will be regulated. The Categorical breakdown of operations is shown in Table I-1 for each airport selected and is explained below:

Table I-1

CY1972 Categorical Breakdown of Operations

	JFK	%	LAX	%	ORD	%
FAA - ATA	369,418		485,280		670,737	
MILTARY	- 1,048	0.3	- 7,378	1.5	- 3,585	0.5
	368,370		477,902		667,152	
GA & LOCAL	- 21,401	5.8	- 56,055	11.6	-40,068	6.0
	346,969		421,847		627,084	
AT	-28,338	7.7	-50,284	10.4	-45,477	6.8
AC	318,631		371,563		581,607	
AAS	-238,564	64.6	-291,394	60.0	-558,744	83.3
	80,067		80,169		22,863	
FF	-48,215	13.0	-7,470	1.5	-10,092	1.5
	31,852		72,699		12,771	
I-S	0	0	-56,668	11.7	0	0
SUP	31,852	8.6	16,031	3.3	12,771	1.9

Air Carrier (AC)

The breakdown of AC into aircraft type includes four major categories. Table 7 of Airport Activity Statistics of Certificated Route Air Carriers[9] (AAS), published jointly by the CAB and FAA, presents the great majority of AC departures (LTOs) per aircraft type. The AAS data do not include Foreign-Flag, Intra-State or Supplemental Air Carriers which are included in the Table 4, FAA Air Traffic Activity[11], total.

Foreign-Flag (FF) LTOs are determined by searching and counting scheduled flights into a particular city by foreign-based carriers as found in the ICAO publication Traffic Flow - December 1972[14]. The assumption is made that flights to and from the chosen city are made to the major airport

under study at that city. The total number computed is then divided by two to change flights to LTOs. This number is multiplied by 12 to obtain the yearly LTOs, which are then multiplied by the "percent scheduled departures completed" for international flights at that airport as found in the AAS. Care must be taken to include only foreign-based airlines (including Canada and Mexico). The ICAO and FAA-CAB have different definitions of an international flight, so some of the international flights of ICAO will not be appropriately adjusted by the percent scheduled departures completed by international flights as determined by FAA. But, the flights that conflict within the definitions are so few and adjustment percentages are so very similar for domestic and international flights that this procedure will result in very minor error. Table I-2 summarizes the 1972 FF LTOs for the selected airports.

Table I-2

1972 Foreign Flag Aircraft LTOs for Selected Airports

Aircraft Type	JFK	LAX	ORD
B707	5766	931	783
B720	516	0	0
B720B	0	134	0
B727	168	0	0
B747	5832	372	979
DC-8	2952	2013	1146
DC-8-61/63	2190	0	0
DC-9	4650	0	2132
DC-10-30	12	0	0
VC-9	18	0	0
VC-10	2448	285	6

Intra-State (I-S) LTOs are obtained from the total flights per week listed in the Offical Airline Guide (OAG), North American Division[10]. The total flights per week are multiplied by both 52 weeks and by the AAS domestic "percent scheduled departures completed" factor for the specific airport to obtain an estimate of the yearly total of LTOs. Care must be taken only to include those carriers officially set aside in the OAG as Intra-State Air Carriers who fly specifically into the airport in the city observed. Each flight has the airplane type flown on that flight listed in the OAG. Thus, the percentage of LTOs per year of each aircraft type can be estimated and applied to the total I-S LTOs for the year to obtain an estimate of yearly LTOs per aircraft type. Although the OAG reference is limited to weekly scheduling as of August 1, 1975, the use of a percentage for each aircraft applied to the total I-S LTOs is felt sufficiently accurate because the fleet mix is not likely to drastically change although the total usage may change significantly from week to week and year to year. Only at LAX was I-S Air Carrier operations found to be of significance. Table I-3 summarizes the I-S activity at LAX.

Table I-3

1972 Intrastate Aircraft LTOs at LAX

Aircraft Type	LTOs
B727-200	25531
B737	459
L-188	815
L1011	1529

The total operations attributed to Supplemental Air Carriers at a specific airport is the remainder after subtracting the sum of the AAS, adjusted I-S and FF LTOs, multiplied by 2, from the total Air Carrier operations of Table 4, FAA Air Traffic Activity[11]. The number of Supplemental Air Carrier operations is then distributed among the Supplemental Air Carrier fleet by the following method.

Total departures of all Supplemental Air Carriers for 1972 are found in the ICAO publication Non-Scheduled Air Transport 1972[15]. Only the top seven carriers of the 12 listed are used (Capitol, McCulloch, Modern, Overseas, Saturn, Trans-International, and World Airways) since of the other five, by 1975 only one, Johnson Air Service, was still certified. However, Johnson Air Service did not have a fleet capable of reaching the major U.S. airports included in this study from its base in Missoula, Montana. From the total departures the weighted percentages for each carrier are determined and applied to the number of supplemental operations at each airport selected. Table I-4a summarizes the supplemental operations. As a minor adjustment, the fleet for McCulloch Airways has been halved and the Overseas National Airways fleet has increased by 50 percent from 1972 to 1975. As a result, half of the operations attributed to McCulloch are redistributed to the enlarged fleet of Overseas to give a more updated picture for 1975. The Supplemental Air Carrier fleet mix is shown in Table I-4b.[16]

Table I-4a

1972 Estimated Supplemental Airline Operations for Selected Airports

Airline	Fraction of Total	JFK	LAX	ORD
Capitol	0.0556	1771	891	710
McCulloch	0.0581	1851	931	742
Modern	0.0348	1108	558	444
Overseas	0.3361	10705	5388	4293
Saturn	0.2804	8931	4495	3581
Trans-Int'l	0.1012	3223	1622	1292
World	0.1338	4262	2145	1709

Table I-4b

1972 - 1975 Supplemental Airline Fleet Mix

Airline	Aircraft Type	Number
Capitol	DC-8-20/30	4
	DC-8-50/62	1
	DC-8-61/63	5
McCulloch	DC-8-20/30	1
	L-188	4
Modern	CV-990	8
Overseas	DC-8-20/30	7
	DC-8-61/63	4
	DC-9-30	5
	DC-10-30	2
Saturn	DC-8-61/63	3
	L-188	9
	L-100-30	12
Trans-Int'l	DC-8-61/63	8
	DC-10-30	3
World	DC-8-61/63	5
	B747	3
	B727-100	4
	B707-320C	2

Each estimate of operations per supplemental Air Carrier per airport is then divided by two and distributed among each carrier's fleet to determine LTOs per aircraft type at a selected airport. Since the fleet mix is heavily weighted by long range jets it is reasonable to assume LTOs per aircraft type at a selected airport are in proportion to the fleet mix. Finally a sum is made of LTOs per aircraft type for each airport selected as summarized in Table I-4c.

Table I-4c

1972 Supplemental Airline Aircraft LTOs for Selected Airports

Aircraft Type	JFK	LAX	ORD
DC-8-20/30	2621	1319	1051
DC-8-50/62	89	45	36
DC-8-61/63	4124	2075	1654
DC-9-30	1487	748	596
DC-10-30	1034	520	415
B707-320C	305	154	122
B727-100	609	307	244
B747	457	230	183
CV990	554	279	222
L-188	2415	1216	969
L-100-30	2223	1123	895

All the tables of Foreign-Flag, Intra-State, and Supplemental Air Carrier LTOs by aircraft type are combined with the AAS data (already broken down into LTOs per aircraft type) to obtain the overall Air Carrier LTOs per aircraft type for 1972 as summarized in Table I-5.

Table I-5

1972 Air Carrier LTOs for Selected Airports

Aircraft Type (Engines)	JFK	LAX	ORD
BAC111-200 (2RR-SPEY-MK506) -400 (2RR-SPEY-MK511)	3216	0	525
B727-100 (3JT8D) -200 (")	37572	59556	96531
DC-10-10 (3CF6-6D1)	1764	16860	8503
DC-10-20 (3 JT9D)	0	0	0
DC-10-30 (3CF6-50)	1046	1560	1244
B707-100B (4JT3D) -300B (") -300C (") B720B (") DC8-50/60 (")	54804	62993	56990
B747 (4JT9D)	18069	12447	10227
DC9-10 (2JT8D) -30 (") B737-200 (")	8852	24397	62181
B720 (4JT3C)	543	9184	1987
DC-8-10 (4JT4A) -20 (") -30 (") B707-300 (")	11545	7889	9189
L1011 (3RR-RB211)	1382	1924	773
CV580 (2 A11. 501-D13)	16	0	0
CV880 (4CJ805-3)	2059	830	12271
CV990 (4CJ805-23B)	554	279	222
VC9 (4RR CONWAY) VC10 (")	2466	285	6
L100-20/30 (4 A11.501-D22A)	2234	1559	1150
L188 (4 A11.501-D13)	2428	2031	972
Falcon (2 TFE731-2)	3	0	0
FH-227 (2RR-DART7-532)	841	0	8218

Table I-5 (Continued)

Aircraft Type (Engines)	JFK	LAX	ORD
F-27 (2RR-DART6-514)	0	3156	1
Jetstar (4TFE731-2)	0	0	5
DeHavilland Twin Otter (2PT6A-27)	0	0	3

Air Taxi (AT)

The Official Airline Guide (OAG), North American Edition[10] is used to determine the total number of flights per week. Such flights are designated as Commuter Air Carriers and exclude Intra-State, Foreign-Flag and Supplemental which are included under Air Carrier above. To prevent double counting only non-stop flights into the airport selected are counted.

Each flight listed in the OAG also includes the type of airplane flown. Thus, after totaling the number of flights per week per airplane type, a breakdown of percent LTOs per aircraft type can be obtained. The total AT operations from Table 4 of FAA Air Traffic Activity[11], is divided by two and multiplied by each percentage to obtain an estimate of the LTOs per aircraft type per year. Although the OAG reference is limited to weekly scheduling as of August 1, 1975, the use of percentages for each aircraft applied to the total AT LTOs, whether for CY 1972 or CY 1975, is felt sufficiently accurate. The fleet mix is not likely to drastically change although the total usage may change significantly from week to week and year to year. Table I-6 summarizes the LTOs per AT aircraft type per year for 1972.

Table I-6

1972 Air Taxi LTOs for Selected Airports

Aircraft Type	JFK	LAX	ORD
DeHavilland Twin Otter	4350	14661	403
S B & H Skyliner	0	1567	0
Convair 580	0	458	0
Sikorsky S-55 *	0	5715	0
Bell 47J2 *	0	2743	0
Beechcraft 99	1814	0	8452
Cessna 402	0	0	1274
Swearingen Metro	0	0	10733
General Prop A/C	199	0	1878
Piper Navaho	1091	0	0
Sikorsky S-61 *	6722	0	0

*Helicopter.

General Aviation (GA)

General Aviation data acquistion suffers from the very minimal compilation of statistics on GA activity for specific airports. The General Aviation Activity Survey[17] for 1972 developed by the FAA is a very good breakdown of GA on a national basis. With minor alterations (for more Air Taxi, less executive flying, etc.) the Survey could easily be used for fleet projection at predominantly GA oriented airports, for which activity statistics are apparently unavailable.

However, at some predominantly Air Carrier airports the GA fleet mix is skewed because the required landing speed is substantially high and

only the larger GA aircraft can land[18]. GA aircraft usually are required to use the same runways as the AC aircraft. With the longer delays and taxi-idle times at these airports, the GA fleet mix is skewed toward business and executive flying and other purposes of particular importance in contrast to personal flying as defined in the above Survey on page 4. Thus, more turboprop and turbojet aircraft are implied in the large AC airport GA fleet mix compared to the national estimates of the Survey.

In order to obtain a better estimate of the GA fleet mix at the particular airports selected, individuals knowledgeable of GA activities at each airport were contacted by telephone. Each AC airport appears to have a business establishment (Butler Aviation at O'Hare, AiResearch Corp. at Los Angles International) catering to this segment of the airport activity. The New York Port Authority which operates John F. Kennedy International compiles statistical information on GA at JFK. In the case of business establishments, the knowledgeable persons are connected with the dispatch or servicing of GA aircraft and can give rough, categorical estimates of the GA activity in percentages by turbojet, turboprop, large piston and small piston GA aircraft. Similar, but presumably more accurate breakdowns of activity are available from the New York Port Authority. Examples of aircraft by model are obtainable, but without a breakdown in percent by model. From the models of aircraft, representative engines for each category can be selected.

Using Tables 24 and 25 of the 1973 Census of U.S. Civil Aircraft[13], the number of planes of each model operating in GA can be found on a national basis. Applying these numbers to obtain ratios within each category provides an estimate of the model breakdown by percentage within the category (assuming the national GA fleet is spread uniformly throughout the country). The percentages are then applied to total LTOs by model. Although the categorical breakdown is based on data from 1972 to 1975, this procedure is believed to provide a more accurate and credible estimate of the number of LTOs per model for GA at the AC airports selected than could be estimated from the FAA General Aviation Activity Survey directly.

Examples of this estimating procedure for the selected AC air ports follows:

General Aviation Activity at O'Hare Airport (ORD)

Based on conversation with Tom Connel, Chief Dispatcher, Butler Aviation, at ORD on July 31, 1975, the following fleet mix was estimated for General Aviation activity at ORD:

50% turbojet

20% turboprop (King Air, Cessna 441)

30% piston (Cessna 310)

An additional piece of information reported is that all aircraft landing at ORD must maintain a speed of at least 200 knots on approach. This almost eliminates single-engine piston aircraft LTOs. Tom Connel also estimated that DC-3 or Martin 404 aircraft have at most 2 or 3 LTOs per week (out of approximately 400 GA LTOs per week). The engine categories for this fleet mix include:

50% turbojet (JT12A, CJ610, CF700, JT15D)

20% turboprop (PT6A-27)

30% piston (TS10-520)

The representative engine percentages for each category (by proportional number of aircraft registered as General Aviation in 1973--Tables 24 and 25 of Census of U.S. Civil Aircraft[13]) are:

50% turbojet	12.19%	CF700 (148)
	17.13%	CF610 (208)
	14.09%	JT12 (171)
	6.59%	JT15 (80)
20% turboprop		(PT6A-27)
30% piston		(TSIO-520)

These percentages are then applied to the total GA LTOs (operations) obtained from FAA Air Traffic Activity[11] (1972) and the Terminal Area Forecast[1-3] (1975-1985) to determine LTOs per engine type. All represented aircraft have two engines.

General Aviation Activity at Los Angeles International Airport (LAX)

In conversation by telephone with Mike Castro, Customer Relations Director, AiResearch, LAX, the following fleet mix was estimated for GA activity at LAX:

75% turbojet (Learjet, Jetstar, Grumman G-2, Dassault Falcon)
15% turboprop (King Air)
9% larger piston (Cessna 310)
1% small piston (Cessna 150)

Air Traffic Controllers require small piston aircraft to approach at cruise (approximately 130 knots as estimated by Mr. Castro). This allows some small piston aircraft to land as shown in the fleet mix. A separate runway exists at LAX for small planes but is used very rarely. The small runway is primarily used by Butler Aviation and AiResearch, who have facilities at the south end of LAX near this runway.

The representative engine percentages for each category are as follows (by number of aircraft registered as General Aviation in 1973 - Table 24 of Census of U.S. Civil Aircraft[13]):

75%	turbojet			
	Learjet	26.62%	CJ610	(208)
	Grumman G-1159	15.10%	Spey 511	(118)
	Jetstar (L1329)	14.85%	TFE731	(116)
	Falcon	18.43%	CF700	(144)
15%	turboprop		PT6A-27	
9%	larger piston		TSIO-520	
1%	small piston		IO-520	

Again, these percentages are applied to total GA LTOs found for LAX. The small piston category is assumed to include only single-engine aircraft. All other categories have two engines per aircraft with the exception of the Jetstar.

General Aviation Activity at John F. Kennedy International Airport (JFK)

In phone conversations with Joe Windisch of the New York Port Authority, the following fleet mix was quoted for both 1972 and 1975 for GA activity[19].

1972	1975	Weight Class	Type
21.6%	8.4%	>30,000#	Large Jet & Turboprop
18.7%	27.1%	12,500-30,000	Small Business Jet
16.1%	26.0%	7,500-12,500	Small Turboprop
24.4%	26.0%	3,000-7,500	Small Twin Engine Piston
19.2%	12.5%	<3,000	Single Engine Piston

The large jets and turboprop aircraft in GA are expected to continue dropping in usage in favor of the small business jets. Thus, aircraft such as the F27, Gulfstream 1 & 2 and Jetstar will likely be supplanted by Learjets, Saberliners and Falcons. The small turboprop and twin piston engine aircraft fleet is expected to increase with the trend to smaller business aircraft, however, the small single piston engine aircraft fleet is expected to diminish rapidly, in terms of numbers of operations at JFK. Overall, GA activity is expected to diminish rapidly at JFK to a negligible amount by 1980.

The representative engine mix by percentage for each category is as follows (by number of aircraft registered as General Aviation in 1973 - Tables 24 and 25 of Census of Civil Aircraft[13]). The large jet and turboprop category has the percentages corrected for the mix of two and four engine aircraft.

1972	1975	Engine Percent
21.6% (Large jet & turboprop)	8.4%	34% Dart 7-532 8% Allison 501-D13 20% Spey Mk. 511 38% TFE 731-2
18.7% (Small Business Jet)	27.1%	11% JT15D 54% CF610 19% CF700 16% Viper 601
16.6% (Small Turboprop)	26.0%	44% TPE 331 56% PT6A-27
24.4% (Small Twin Engine Piston)	26.0%	100% Cont. TSIO-520
19.2% (Single Engine Piston)	12.5%	100% Cont. IO-520

The percentages are applied to the total GA LTOs found for JFK.

General Aviation Comment

In the overall study the GA section has been maintained separately to facilitate the infusion of hard statistics at a later date. The approximations and estimates are believed reasonable because emission characteristics do not vary greatly within the general GA categories, and more importantly, GA activity will be phased out or reduced to less than 1% in the near future at the major AC airports selected. Table I-7 summarizes the engine LTOs for GA at selected AC airports.

Table I-7

1972 Engine LTO's for General Aviation at Selected Commercial Airports

Engine Type	JFK	LAX	ORD
CF 700	760	10331	4884
CJ 610	2161	14922	6864
JT 12	0	0	5646
JT 15D-4	440	0	2640
Spey MK511	925	8464	0
TFE 731	1757	8324	0
PT 6A-27	1930	8408	8014
TPE 331	1516	0	0
Viper 601	640	0	0
Allison 501-D13	370	0	0
Dart 7-532	1572	0	0
TSIO-520	5222	5044	12020
IO-520	2055	280	0

Auxiliary Power Units (APU)

Duty time data for APUs, defined as the time per LTO in which the APU is operating, are not extensive. Three reports from airlines were received in private communications from AiResearch Corp. These

reports disclose a very wide range of duty times among the airlines not only with respect to dissimilar aircraft but even with respect to the same aircraft types. AiResearch provided average numbers for small, medium and large APU duty times with the reports, but because APU emission data exist and vary widely for the variety of APUs, a more detailed estimate has been prepared.

In order to reduce the impact of error due to the wide range of duty times, a three factor procedure is used. Lowest, highest, and average duty times are computed from the shortest, longest and mean time periods attributed to each aircraft APU duty time. The variation between lowest and highest emissions can cause total baseline airport emission from aircraft to vary as much as 1% for HC, 2% for CO and 6% for NOx. The variation in duty times is by a factor of two or more between the lowest and highest. Thus, the lowest and highest values should not be used other than to obtain an emission range. An arithmetic mean or median number could ease the dilemma as to which data are more accurate, and lessen any possible error. Unfortunately, there is no indication in the data of the effect the time the APU is utilized on overnight layovers has on the average duty time. The computation of such an average number having adequate accuracy is therefore difficult.

The following classes of aircraft, are used to determine the duty times:

1) Medium range jets (727, 737, DC9, BAC111)
2) DC-10 and L1011
3) B747

The DC-10 and L1011 are added as a separate class because only one duty time data point was obtained and is substantially less than the averages for the medium size jets and any of the B747 data. The DC-10 and L1011 (along with the B747) are certified by the FAA to operate the APU during climbout, in-flight and descent modes of operation, unlike the medium size jets. The DC-10 and L1011 are approximately mid-way between the medium jets and B747 in size, therefore the data point was adjusted accordingly to make the APU duty times consistent with respect to size of aircraft, a trend the data generally appears to indicate. More detail would require a statistical study of actual APU duty times at each of the selected airports for each size of aircraft and possibly each type of aircraft in a manner similar to studies of average taxi-idle time discussed below.

Both the median and arithmetic mean was found for each class. For the medium jet classes the mean and median correspond very closely. 80 minutes is used as the duty cycle average time for this class. For the B747, the arithmetic mean, rounded off to 180 minutes, is selected since it appears to best compensate for the data spread. However, both these duty times selected as representative are only best estimates. The DC-10 and L1011 duty time is selected as an intermediate mean between the medium jet and the B747 classes (130 minutes per LTO).

The final results are as follows:

	Duty Cycle Time (Minutes)		
Class	Lowest	Highest	Representative Time*
Medium Jet	30	120	80
DC-10 and L1011	85	205	130
B747	145	295	180

* does not represent average of best and worst case but is based on round off of the average of actual data received.

The appropriate representative time is combined with the LTOs for each type of aircraft and the emission factors for the particular APU unit on board that aircraft. The APU computations do not include the contribution of ground based units nor do the computations include the ground based operation (outside of taxi-idle time) of the main engines on those aircraft unequipped with APUs. Some business and executive GA jets are equipped with APUs, however, for purposes of this study such contribution has been neglected as of negligible importance. Table I-8 summarizes the use (LTOs) per year for 1972 of APUs at the selected AC airports.

Table I-8

CY1972 Auxiliary Power Unit Use (LTOs) at Selected Commercial Airports

Aircraft	APU	Time*	JFK	LAX	ORD
BAC 111	GTCP 85-115	80	3216	0	525
B 727	GTCP 85-98	80	37572	59556	96775
DC-10	TSCP 700-4	130	2810	6140	8918
B 747	GTCP 660-4	180	18069	12447	10227
DC-9	GTCP 85-98	80	8813	7396	43203
L1011	ST6C	130	1382	1924	773
B 737	GTCP 85-129	80	39	17001	18978
L 188	GTC 85-90+	80	2428	2031	972

* Minutes
\+ GTCP 85-98 Data

Determination of Taxi-Idle Time at Selected Airports (T-I)

Because of the relatively high HC and CO emissions of gas turbine engines at very low thrust or power levels, the typical taxi-idle (T-I) time is estimated for each of the selected airports by the following procedure.

For purposes of this study T-I time includes two major parts. The first part is the time an AC aircraft takes from touchdown until the engines are shut down at the gate. Added to this is the departure time from engine start-up until the start of the take-off run of the aircraft. Some of the data obtained broke down these two parts further, however, all the data includes the same total time period with the same end points.

No official U.S. statistical service which undertakes compilations of aircraft data were located having data for T-I times. The most important source of data is a series of tables compiled by four major airlines (TWA, American, Eastern, and United) estimating time breakdowns for the various ground operations of the aircraft[20]. Two additional studies give second-hand, observed information for Los Angeles International[5] and Chicago O'Hare International[21]. The data is summarized in Table I-9 and mean taken to determine the average taxi-idle times at LAX, ORD and Kennedy International (JFK).

Table I-9

Taxi-Idle (T-I) Times at Selected Commercial Airports

Airline	JFK+	LAX+	ORD+
TWA	33.00	24.00	28.00
AA	31.50*	24.00*	30.50*
EA	33.00	---	---
UAL	26.00	15.00	22.00
Ref. 1-13	---	20.80	---
Ref. 1-14	---	---	15.80
Average T-I Time	31	21	24

* Based on arithmetic average of data given
\+ Time in minutes

The data used for this study is very limited and based on estimates and observations. The times are fairly consistent at each airport. A more comprehensive data set with more observations at each airport is required if a more accurate average taxi-idle time is desired. At present, more data on average taxi-idle times for commercial air transports is apparently not available. T-I times for AT and GA are assumed equal to that above for AC because the same runways and taxiways are utilized for all aircraft with the exception of a few GA flights on a small runway at LAX.

The T-I time for each airport selected is combined with emission factors for idle mode on an hourly basis and flight mode emission factors for each type of aircraft to calculate the emission factors for each type of plane at each airport as explained below.

Emission Factor (E.F.) Calculations

The emission factors are tabulated in Tables I-10, I-11 and I-12 for each engine type used by aircraft at that airport. The flight mode and idle mode data utilized to calculate the emission factors was the best available to EPA at the time this study was commenced and was obtained from a wide variety of engine manufacturers, industry groups and other government agencies. Although much of the emissions data available to EPA has been updated subsequent to commencement of this study, the overall results of the study would be negligably affected by the inclusion of more recent emission factor data for some of the engines. The tables labeled "current" comprise emission factors for engines currently in use and are utilized for calculations pertaining to 1972

and 1975. The tables labeled "modified" comprise engines modified or new as a result of EPA 1979 standards and are incorporated into the calculations for 1980 and 1985 as appropriate to account for the portions of the aircraft fleet having engines manufactured after the implementation dates of the EPA standards.

Each engine emission factor incorporating the pertinent T-I time for each selected airport is calculated using the following equation:

$$E.F._{airport} = (E.F._{T-I}) * (T\text{-}I_{time}/60) + E.F._{flight\ mode}$$

where

$E.F._{airport}$ is in lbs./LTO

$E.F._{T-I}$ is in lbs./hr.

$E.F._{flight\ mode}$ is in lbs./LTO

$T\text{-}I_{time}$ is in minutes

Table I-10

Computed Engine Emission Factors (JFK)

31 Min. - Taxi Idle — Current Engines — (Lbs/LTO)

Engine	HC	CO	NOx	Engine	HC	CO	NOx
JT9D	25.0	71.4	26.4	CJ 805-3B	14.3	37.2	6.0
JT8D	6.7	28.1	10.9	CJ 805-23B	13.7	35.7	5.8
JT3D	61.5	73.5	6.3	CJ 610-6	5.0	51.0	0.82
JT3C	25.0	54.8	6.2	CF 700-2D	4.4	44.0	0.93
JT4A	80.2	82.4	8.1	CF 6-6D1	21.2	49.0	20.8
Spey	34.4	34.4	8.5	CF 6-50A	22.6	57.2	32.4
MK 511				PT6A-27	2.6	3.7	0.35
MK 506				TFE 731-2-3	2.4	6.2	1.6
RB-211-22B	21.1	58.4	19.8	TPE 331-3	5.1	4.0	0.64
RR-Conway	48.5	68.3	13.2	Allison			
M45H	7.1	35.9	2.33	501D-13	3.8	8.5	2.5
Dart 7-532-7	2.6	2.3	1.4	501D-22A	4.1	3.7	2.2
Dart 6-514	2.3	2.0	1.2	Continental			
JT15D-4	3.9	10.2	1.1	TSIO-520	1.35	22.7	0.11
Viper 601	4.4	44.0	0.93	IO-520	1.17	26.8	0.063

Modified and New Engines after 1979

JT9D-7	4.30	23.2	14.3	CJ 610-6	3.0	52.3	0.82
JT9D-70A	4.42	24.0	14.4	CF 700-2D	2.6	45.2	0.92
JT8D-217	1.59	8.5	5.3	CF 6-6D	3.22	17.2	10.3
JT3D-3B	34.4	48.5	9.36	CF 6-50A	3.84	20.6	12.4
JT15D-4	0.46	2.72	0.97	TFE 731-3	0.66	3.87	1.36
PT6A-41	0.43	2.33	0.66	RB 211-22B	2.83	15.2	9.2
PT6A-27	0.34	1.89	0.48	M45H	1.26	7.4	2.33
TPE 331-3	0.44	2.40	0.64	Spey	3.85	11.6	9.00
CFM 56	1.19	10.1	6.2	MK 511			

Table I-11

Computed Engine Emission Factors (LAX)

21 Min. - Taxi Idle

Current Engines (Lbs/LTO)

Engine	HC	CO	NOx
JT9D	17.03	48.98	24.98
JT8D	4.57	19.73	10.22
JT3D	41.86	51.26	5.93
JT3C	17.07	38.02	5.70
JT4A	54.54	57.58	7.74
Spey MK 511 MK 506	23.43	24.41	8.34
RB-211-22B	14.81	43.41	19.55
RR-Conway	32.94	47.58	12.47
M45H	4.99	25.89	2.16
Dart 7-532-7	1.74	1.68	1.304
Dart 6-514	1.52	1.47	1.14
PT6A-27	1.78	2.60	0.31

Engine	HC	CO	NOx
CJ805-3B	9.74	26.58	5.75
CJ805-23B	9.31	25.48	5.50
CJ610-6	3.44	37.79	0.75
CF700-2D	3.01	32.13	0.86
CF6-6D1	14.34	33.41	20.08
CF6-50A	15.33	39.10	31.73
TFE 731-2-3	1.63	4.43	1.54
TPE 331-3	3.42	2.940.58	
Allison			
501 D-13	2.62	5.91	2.22
501 D-22A	2.76	2.67	2.07
Continental			
TSIO-520	0.97	19.26	0.11
IO-520	0.85	24.39	0.06

Modified and New Engines After 1979

JT9D-7	2.97	15.9	13.02
JT9D-70A	3.07	16.45	13.21
JT8D-217	1.11	6.03	4.82
JT3D-3B	23.37	33.74	8.84
CFM56	0.83	7.34	5.79
PT6A-41	0.30	1.65	0.55
PT6A-27	0.24	1.34	0.41
TPE 331-3	0.30	1.66	0.58

CJ610-6	2.11	38.68	0.75
CF700-2D	1.80	32.93	0.85
CF6-6D	2.18	11.75	9.92
CF6-50A	2.61	14.06	11.79
TFE 731-3	0.48	2.79	1.28
RB211-22B	1.97	10.62	8.82
Spey MK 511	2.61	7.86	8.83
Continental TSIO-520 IO-520	0.50	11.09	0.40

Table I-12

Computed Engine Emission Factors (ORD)

24 Min. - Taxi Idle

Current Engines (Lbs/LTO)

Engine	HC	CO	NOx
JT9D	19.43	55.72	25.40
JT8D	5.19	22.23	10.42
JT3D	47.76	57.94	6.03
JT3C	19.45	43.05	5.84
JT4A	62.24	65.03	7.85
Spey MK 511 MK 506	26.73	27.42	8.38
RB211-22B	16.68	47.91	19.62
RR-Conway	37.62	53.80	12.69
M45H	5.61	28.9	2.21
Dart 7-532-7	1.98	1.87	1.34
Dart 6-514-7	1.73	1.63	1.67
CF 700	3.42	35.69	0.88
CJ610, JT12	3.90	41.97	0.77
JT15D-4	3.06	8.13	1.00

Engine	HC	CO	NOx
CJ805-3B	11.10	29.77	5.83
CJ805-23B	10.62	28.54	5.58
CF6-6D1	16.39	38.06	20.23
CF6-50A	17.52	44.53	31.93
TFE 731-2-3	1.85	4.96	1.56
TPE 331-3	3.91	3.11	0.60
Allison			
501D-13	2.98	6.69	2.31
501D-22A	3.15	2.97	2.12
PT6A-27	2.03	2.92	0.32
Continental			
TSIO-520	1.09	20.30	0.11
IO-520	0.95	25.10	0.62

Modified and New Engines After 1979

JT9D-7	3.37	18.10	13.39
JT9D-70A	3.47	18.70	13.56
JT8D-217	1.25	6.77	4.96
JT3D-3B	26.69	38.16	9.00
CFM56	0.94	8.16	5.92
PT6A-41	0.34	1.85	0.58
CF6-6D	2.49	13.39	10.03
CF6-50A	2.98	16.02	11.96
TFE731-3	0.53	3.11	1.30
RB211-22B	2.23	12.00	8.93
M45H	1.01	5.94	2.21
TPE-331-3	0.34	1.88	0.59

The emissions factors for APU's are summarized in Table I-13.

Table I-13

Auxiliary Power Unit Emission Factors

All Airports (lbs/hr)

Engine	HC	CO	NOx
Current			
GTCP85-98	0.050	1.907	1.730
" -115ck	0.009	1.430	1.641
" -129	0.055	2.363	1.516
GTCP 660-4	0.24	9.50	5.84
TSCP 700-4	0.12	0.61	4.54
ST6C	0.51	2.78	4.00
Modified			
GTCP 85-98	0.04	1.40	0.84
GTCP 660-4	0.20	6.00	3.60
GTCP 700-4	0.09	0.55	2.25
ST6C	0.10	0.60	2.46

Final Total Aircraft Emissions Calculations

The final calculations require the following items of data from the preceeding calculations.

1) The breakdown of LTOs per aircraft type per airport.

2) The emission factors per engine type per airport ($E.F._{airport}$).

3) The number and type of engine on each aircraft.

4) The type of auxiliary power unit (APU) on those aircraft so equipped.

5) The emission factors for APUs (E.F. in lbs/hr).

6) The representative duty time per LTO for APUs.

For each aircraft type at a selected airport the following equation is used to determine emissions:

$$(\#LTOs) * (\#\ engines) * (Engine\ E.F._{airport}) = Emissions\ per\ type_{HC,\ CO,\ NOx}$$

By units, this is:

$$\frac{(LTO - Aircraft)}{Year} * \frac{(Number\ of\ Engines)}{Aircraft} * \frac{(Lbs.\ pollutant)}{Engine\text{-}LTO} = \frac{(Lbs.\ pollutant)}{Year}$$

And the results summarized in Tables I-14 through I-22 inclusive:

TABLE I-14

1972 Air Carrier Emissions for JFK

AIRCRAFT TYPE	*HC	CO	NOx
BAC 111-200 -400	221,261	221,261	54,672
B727-100 -200	755,197	2,457,209	1,228,604
DC-10-10	112,190	259,308	110,074
-20	0	0	0
-30	70,919	179,494	101,671
B707-100B -300B -300C -B720B DC-8-50/60	13,481,784	16,112,376	1,381,061
B747	1,806,900	5,160,506	1,908,086
DC-9-10 -30 B737-200	118,617	497,482	192,974
B720	54,300	119,026	13,466
DC-8-10 -20 -30 B707-300	3,703,636	3,805,232	374,058
L1011	87,481	242,126	82,091
CV580	122	272	80
CV880	117,775	306,379	49,416
CV990	30,359	79,111	12,853
VC9 VC10	478,404	673,711	130,205
L100-20/30	36,638	33,063	19,659
L188	36,906	82,552	24,280
FALCON	14	37	10
FH-227	4,373	3,869	2,355
F-27	0	0	0
JETSTAR	0	0	0
DTO	0	0	0

*LBS/YR

Table I-15

1972 Air Carrier Emissions For LAX

Aircraft Type	*HC	CO	NOx
BAC 111-200	0	0	0
-400	0	0	0
B727-100	816,513	3,525,120	1,825,987
-200			
DC-10-10	241,772	563,293	338,549
-20	0	0	0
-30	23,915	60,996	49,499
B707-100B			
-300B			
-300C	10,547,548	12,916,085	1,494,194
B720B			
DC-8-50/60			
B747	847,890	2,438,616	1,243,704
DC-9-10	222.989	962,706	498,675
-30			
B737-200			
B720	156,771	349,176	52,349
DC-8-10			
-20			
-30	1,720,955	1,816,879	244,228
B707-300			
L1011	85,483	250,563	112,843
CV580	0	0	0
CV880	32,320	88,246	19,090
CV990	10,390	28,436	6,138
VC9	0	0	0
VC10	37,552	54,241	14,216
L100-20/30	17,211	16,650	12,909
L188	21,285	48,013	18,035
Falcon	0	0	0
FH-227	0	0	0
F-27	9,594	9,279	7,196
Jetstar	0	0	0
DTO	0	0	0

*Lbs/Yr

Table I-16

1972 Air Carrier Emissions For ORD

Aircraft Type	*HC	CO	NOx
BAC111-200	28,067	28,791	8,799
-400	0	0	0
B727-100			
-200	1,506,787	6,453,925	3,025,187
DC-10-10	418,093	970,873	516,047
-20	0	0	0
-30	21,786	55,373	39,705
B707-100B			
-300B	10,887,274	13,207,887	1,374,587
-300C			
B720B			
DC-8-50/60			
B747	794,842	2,279,394	1,039,063
DC-9-10			
-30	645,439	2,764,567	1,295,852
B737-200			
B720	154,589	342,161	46,416
DC-8-10			
-20	2,287,693	2,390,243	288,535
-30			
B707-300			
L1011	38,681	111,103	45,499
CV580	0	0	0
CV880	544,832	1,461,231	286,160
CV990	9,431	25,344	4,955
VC9	0	0	0
VC10	903	1,291	305
L100-20/30	14,490	13,662	9,752
L188	11,580	25,997	8,977
Falcon	0	0	0
FH-227	32,543	30,735	22,024
F-27	3	3	3
Jetstar	37	99	31
DTO	12	18	2

*Lbs/Yr

Table I-17

1972 Air Taxi Emissions For JFK

Aircraft Type	HC	CO	NOx
Beechcraft 99	9,430	13,420	1,270
DeHavilland Twin Otter	22,620	32,190	3,045
Piper Navaho*	3,482	58,544	284

* Includes Misc. Propeller Aircraft

Table I-18

1972 Air Taxi Emissions For LAX

Aircraft Type	HC	CO	NOx
DeHavilland Twin Otter	52,191	76,235	8,972
SB & H Skyliner	10,715	12,344	1,827
Convair 580	2,397	5,408	2,031

Table I-19

1972 Air Taxi Emissions For ORD

Aircraft Type	HC	CO	NOx
DeHavilland Twin Otter	1,634	2,350	256
Beechcraft 99	34,315	49,360	5,375
Swearingen Metro	83,928	66,756	12,879
Cessna 402	2,763	51,699	275
Misc. Propeller Aircraft	13,982	11,121	2,146

Table I-20

1972 General Aviation Emissions for JFK

Engine Type	HC	CO	NOx
Dart 7-532	4,087	3,616	2,201
Allison 501-D13	1,406	3, 145	925
Spey 511	31,820	31,820	7,863
TFE 731-2	4,217	10,893	2,811
JT15D	1,716	4,488	484
CJ610	10,805	110,211	1,772
CF700	3,344	33,440	707
Viper 601	2,816	28,160	595
TPE 331	7,732	6,064	970
PT6A-27	5,018	7,141	676
TCM TSIO-520	7,050	118,539	574
TCM IO-520	2,404	55,074	129

Table I-21

1972 General Aviation Emissions For LAX

Engine Type	HC	CO	NOx
Spey 511	198,269	206,606	70,573
TFE 731-2	13,568	36,875	12,819
CJ610	51,332	567,334	11,162
CF700	31,096	331,935	8,833
PT6A-27	14,966	21,861	2,573
TCM TSIO-520	4,905	97,147	540
TCM IO-520	237	6,829	17

Table I-22

1972 General Aviation Emissions For ORD

Engine Type	HC	CO	NOx
CJ610	13,392	288,082	5,292
CF700	16,703	174,310	4,278
JT12	22,031	236,963	4,353
JT15D	8,078	21,450	2,640
PT6A-27	16,268	23,401	2,548
TCM TSIO-520	13,042	243,982	1,298

For each aircraft APU the following equation is used to determine emissions:

$$(\#LTOs) * (Duty\ time_{LTO}) * (APU\ E.F._{HC,\ CO,\ NOx}) =$$

APU Emissions per aircraft type per airport.

By units, this is:

$$\frac{(LTOs - Aircraft)}{Year} * \frac{(Number\ of\ minutes)}{aircraft\text{-}LTO} * \frac{1}{60} *$$

$$\frac{(Lbs.\ pollutant)}{Hour} = \frac{(Lbs.\ pollutant)}{Year}$$

And the results summarized in Tables I-23, I-24 and I-25:

Table I-23

1972 Auxiliary Power Unit Emissions For JFK

Aircraft Type	HC	CO	NOx
BAC111	39	6,132	7,037
B727	2,505	95,533	86,666
DC10	731	3,714	27,641
B747	13,010	514,967	316,569
DC9	588	22,409	20,329
L1011	1,527	8,324	11,977
B737	3	123	79
L188	162	6,174	5,601

Table I-24

1972 Auxiliary Power Unit Emissions For LAX

Aircraft Type	HC	CO	NOx
B727	3,970	151,431	137,376
DC10	1,596	8,115	60,397
B747	8,962	354,740	218,071
DC9	492	18,806	17,060
L1011	1,063	8,546	16,675
B737	1,247	53,564	34,365
L188	135	5,164	4,685

Table I-25

1972 Auxiliary Power Units Emissions For ORD

Aircraft Type	HC	CO	NOx
BAC111	6	1,001	1,149
B727	6,452	246,067	223,228
DC10	2,319	11,786	87,718
B747	7,363	291,470	179,177
DC9	2,880	109,851	99,655
L1011	854	4,656	6,699
B737	1,392	59,793	38,361
L188	65	2,471	2,242

All of the above calculations per aircraft type per airport are then summed to obtain the total AC, AT, GA and APU emissions for each of the pollutants (HC, CO, NOx) per airport. (See summary Tables I-59, [JFK], I-60 [LAX] and I-61 [ORD]).

For analytical or comparison purposes these above totals are manipulated three more times:

1) Divide by 2000 to obtain tons per year;

2) Divide by 365 to obtain tons per day;

3) Divide by the area of land covered by the airport to obtain an emission density result (tons/day-mile^2).

The primary reason for the further calculations is to compare the data to data which already exists in the three above mentioned forms.

In future years (1980 and 1985) complications arise in the application of emission factors with the advent of newly manufactured engines produced to meet the 1979 emissions standards and the inbreeding of retrofit requirements with regard to some of the large AC engines for emissions and the JT3D for smoke. Thus, in some cases the aircraft LTOs per year for 1980 and 1985 are divided to account for that portion of the fleet with modified or new engines as explained below.

Helicopter Operations

Helicopter operations now comprise a significant portion of the LTOs at John F. Kennedy International Airport. In particular, for CY 1972 S-61 helicopters of New York Airways comprised 8.7% of the departures for Certified Route Air Carriers[9]. However the S-61 flights apparently all occur between the four principle airports of the New York Metropolitan area and as such are more properly classified with the Air Taxi fleet or as local operations. For purposes of this study the helicopters at JFK have been considered Air Taxis and comprise 47% of

the AT fleet. Because helicopter LTO cycles as a function of time typical for the airports selected remain unknown and emissions standards are not anticipated in the near future, an estimate of emissions contribution from helicopter operations is not included in this study. Helicopter operations might better be approached by considering all four New York airports and the entire flights, the major portions of which are below 3000 ft. (914.4 m).

Aircraft Population and LTO Projections to 1985

Aircraft population figures are determined for the calendar years 1972, 1975, 1980, and 1985. As noted above, figures are available from a variety of sources for CY 1972 and some figures from 1973, 1974 and 1975 also are available; however, some projection figures are utilized from earlier sources for 1975 calculations because this study was commenced during calendar year 1975. Predictions of future operations (1980 and 1985) are obtained primarily from the FAA Terminal Area Forecasts[8] for each of the selected airports. However, the predictions for John F. Kennedy International (JFK) are very questionable; they imply a rapid increase in local and general aviation (GA) which contradicts the trend to negligible GA activity before 1980 at JFK and other predominantly commerical aviation airports. Discussion with Joe Windisch of the New York Port Authority indicated that the FAA predictions for increases in AC and GA activity at JFK are not currently accepted by the Port Authority, but, rather that most if not all increases in passenger loading will be absorbed by an increasing load factor and an increasing proportion of wide body jets.[19] Even the shuttle services and possibly the commuter

(AT) increases in passenger loading will be accomodated by increasing the size of the aircraft rather than the number of operations.

Table I-26 for the airports selected is derived by interpolation from corresponding tables listed in the FAA Terminal Area Forecasts,[8] and the FAA Air Traffic Activity 1972.[1-1] The data for 1980 and 1985 are adjusted to be more realistic in the particular case of JFK.

Table I-26

Operations Forecasts for the Selected Airports

	($x10^{-3}$)	CY1972+	FY1975	FY1980	FY1985
JFK	Total	369	346	400	450
	AC	319	299	355	399
	AT	28	31	35	40
	Local(GA)	21	15	10*	11*
	Military	1	1	0	0
LAX	Total	485	475	515	540
	AC	372	366	431	443
	AT	50	56	72	96
	Local(GA)	56	48	11	1
	Military	7	5	0	0
ORD	Total	671	696	735	764
	AC	582	597	656	659
	AT	45	61	79	105
	Local(GA)	40	38	0	0
	Military	4	3	0	0

*Helicopter Only
+Actual

Table I-27

Percent Forecast of Air Carrier Operations
by Equipment Type

	*JFK				*LAX				*ORD			
	'72	'75	'80	'85	'72	'75	'80	'85	'72	'75	'80	'85
B747	11	13	16	20	7	7	9	13	3	3	5	8
DC10/L1011	2	9	15	20	4	15	20	25	3	9	15	19
DC8-61/63	7	3	3	2	5	2	2	1	4	3	2	1
B707/DC8	36	32	19	10	35	25	15	7	23	14	7	3
B727-200	8	10	15	20	23	23	31	34	12	18	26	33
B727-100	14	14	10	4	10	11	5	2	22	20	11	5
B737/DC9	7	13	16	18	13	16	19	18	22	23	30	31
T-PROP	9	--	--	--	3	1	--	--	10	9	4	--
PISTON	--	--	--	--	--	--	--	--	--	--	--	--
HEL'R	6	6	6	6	--	--	--	--	1	1	--	--

*1972 and 1975 are actual percentages

Air Carrier (AC)

The projections are generally obtained as percentages from Table B of the Fleet Projection Tables distributed by the FAA and entitled Equipment Forecast for the Top 25 Air Carrier Airports 1975 - 2000.[12] Table I-27 is obtained from the Equipment Forecast but includes 1972 actual operations derived from Table I-5.

For the Air Carrier sub-grouping, the projected operations are given in the percentage each equipment type will produce of the total Air Carrier operations at the particular airport. The equipment types are further classified into groups that are in operation today or are known to be in the design stage. It is assumed that derivatives of the wide-body jets may be available in the latter part of the forecast period. However, they are classified by today's designation for this forecast. The equipment is broken down into 10 major groups, including both passenger and all cargo models. Each major group and the further development within the group devised in particular for this study are as follows:

747: (includes 747 and derivatives of 747) Due to no definite information as to any derivatives planned beyond the 747 SP, only 747's with JT9D engines are included in this category.

DC10/L1011: (includes DC-10, L1011 and derivatives) This involves four engine types on four aircraft: DC-10-10 with CF6-6D1 engines, DC-10-20 (sometimes labeled DC-10-40) with JT9D powerplants, DC-10-30 powered by CF6-50 engines, and the L-1011 with RB-211 engines. The FAA apparently does not break this total fleet down in any of the data compiled. A procedure disclosed below takes into account the present fleet nationally, specific airport adjustments, and other relevant factors to determine a weighted percentage of LTOs for each type of aircraft. An important problem with the analysis of this category is that all of the planes remain in production.

The DC-10's and L1011's are chosen by different airlines (only Delta has had both types of aircraft at any time). These airlines fly heavily into some major airports and lightly into others, thereby defeating any national average application as being much too gross an estimate. The newly produced aircraft are entering the fleet in somewhat equal proportions year-by-year. But DC-10's still retain an advantage, having entered the fleet in 1971 whereas L1011's were not delivered until 1972. Among specific airports, however, the relative proportions of DC-10's and L1011's change dramatically.

In determining the number of LTOs per aircraft, 5 assumptions are used to set up the intial basis:

(1) DC-10-10's will retain a high percentage of DC-10 U.S. LTOs through 1985 due to the large number of LTOs of this model relative to the other DC-10 models attributed to U.S. airlines and the U.S. domestic orientation of the DC-10-10 over the international orientation of the DC-10-30.

(2) DC-10-20's will retain the same percentage of LTOs through 1985 since Northwest Airlines is the only airline using them domestically at present (15 aircraft). This assumption follows the actual LTOs at ORD, LAX and JFK from 1972 (FAA-AAS)[9] and 1975 (OAG)[10] very closely, however, DC-10-40 (DC-10-20) service began at JFK by Northwest subsequent to 1972.[22] Thus, some alterations can be expected but are difficult to predict. Such changes are not expected to seriously effect the overall analysis because the same size aircraft are being substituted.

(3) DC-10 and L1011 aircraft will remain with the airlines, relative to type, as they stood in 1973. By this assumption, airlines that own only DC-10-10's will continue to own only DC-10-10's and, similarly, for airlines having the other two DC-10's and the L1011.

(4) Based upon assumtion 3 and the fact that individual airlines fly more heavily into some airports and less heavily into others, the ratio of DC-10 LTOs to L1011 LTOs at any specific airport will remain reasonably the same based on 1973 and 1975 data for the specific airports.

(5) U.S. domestic AC (except for Northwest and National) will continue to use DC-10-10's and foreign flag AC will continue to use DC-10-30's.

Two 1975 issues of the Official Airline Guide (OAG), the North American edition for August 1, 1975,[10] and the International Edition for July, 1975,[23] are used to determine the total scheduled LTOs at each selected airport.

The three versions of the DC-10 are broken down by checking each airline against the type of DC-10's included in its fleet. Most airlines include only one type of DC-10. The exception is National Airlines which has mostly DC-10-10's with a few DC-10-30's (Jane's All the World's Aircraft).[9,24] The results are as follows for ORD, LAX and JFK:

Table I-28

	ORD	LAX	JFK
LTO Ratio $\frac{(DC-10)}{(L1011)}$	4.0	2.4	1.2
Fraction of DC-10 LTOs performed by:			
DC-10-10	0.724	0.928	0.767
DC-10-20	0.264	0.000	0.048
DC-10-30	0.012	0.072	0.185
	1.000	1.000	1.000

Utilizing these ratios to breakdown the percentages of DC-10/L1011 aircraft, the LTOs for the individual models are estimated for 1980 and 1985 by applying the resulting percentages to the total AC LTOs.

DC-8 STRETCHED: (includes DC-8-61 and DC-8-63) Due to the fact that both versions use JT3D engines, no breakdown between the versions was implemented.

B707/DC8: (includes all models of B707, all models of standard DC8, B720, CV880, CV990, Jetstar, and all other models of standard body domestic and foreign built four-engine jets). The aircraft LTOs involved in this category are summed and then fractioned to obtain weighted percentages for each model according to 1972 operations. All the aircraft included in the 1972 weighting are out of production and decrease in population forward from that time. The projection was further adjusted by the following considerations:

(1) The JT4A and JT3C, as old turbojet engines, will drop out as powerplants just before 1980, the presently foreseeable latest date of implementation of noise standards. The aircraft powered by these engines will be either converted to JT3D engines or will drop out completely from U.S. service. The percentage of LTOs handled by these aircraft are added to the JT3D-powered aircraft of the same model designation to carry out the conceivable results of this transition.

(2) The CV880 contributed a significant number of LTOs by certificated route AC and the CV990 remained in service with a supplemental AC in 1972 and 1973 (AAS),[9,24] however, by June 1975 the CV880s were all sold to foreign airlines or abandoned and only Modern Air Transport airline retained 9 CV990s for use in the U.S. with the remainder outside of the U.S. Most of Modern's were out of service in 1972 therefore it is reasonable to assume all CV880s and CV990s will be out of U.S. service by 1980.[25]

B727 STR: (includes 727-200 and 727-300 or 7X7 jets) Adjustments to this category are made in the 1980 and 1985 projections due to the advent of the 7X7 in 1979 (estimated). The categorical total of LTOs is found for each of these years from the Equipment Forecast[12] and the airport AC totals.[8] The LTOs are distributed by taking a ratio of the number of aircraft in the AC fleet estimated by the FAA for 1980 and 1985 to arrive at an estimate for each aircraft type.[22] The results are:

Table I-29

	Number of Aircraft	% of LTOs
1980		
727-200	499	82%
7X7 (727-300)	110	18%
1985		
727-200	499	50%
7X7 (727-300)	499	50%

B727-100: (includes all models of the 727-100) No adjustments are necessary for this category and the percentages given for operations are used.

DC9/B737: (includes all models of DC9, B737 and all foreign built, twin-engine, standard body jets) The DC-9 remains in production, while the B737 and BAC1-11 are not, in the 1975 to 1985 time frame. Particular airports are heavily weighted toward either DC-9's or B737's for LTOs. The BAC-111 is projected to drop out by 1981 according to the FAA.[26] Other two engine jets are projected to increase gradually from 1975 to 1986

to take the place of the BAC-111. They are expected to be equivalent in number by 1979 and growing at an accelerated rate from 1980 to 1986. They are assumed to have the same emission factors as the BAC-111 until 1979. For 1980 and beyond the replacement aircraft are assumed to be VFW 614s, the most likely aircraft to replace the BAC-111. Emissions data are available for the RR M45H engine which powers the VFW 614 to permit calculations of probable emissions. Because the two engine replacement fleet (VFW 614) is predicted to more than double from 1980 to 1985, the LTOs are predicted to at least double for the selected airports. For airports that do not include BAC-111 LTOs or equivalent AC LTOs in 1972 and 1975, LTOs are not predicted for 1980 and 1985.

The proportion of DC-9's to B737's at each selected airport is likely to be retained subject to changes to account for the production of further DC-9's, therefore, the following estimating scheme is used:

a) For 1975, the same relative percentage of LTOs are applied as determined from 1972 baseline.

b) For 1980, the B737 and BAC-111 (VFW 614) LTOs are kept constant and the residue applied to the DC-9. The DC-9 fleet is expected to grow by 193 aircraft with the other fleets remaining static in number.[1-20]

c) For 1985, the VFW 614 LTOs are expected to double the percentage determined for 1980. Then for the remainder:

(1) If the categorical percentage is equal or decreasing from 1980 (LAX), retain the DC-9 LTOs constant with the residue B737 LTOs.

(2) If the categorical percentage is increasing (ORD, JFK), retain the B737 LTOs constant with the residue DC-9 LTOs.

Turboprop: (includes all turboprop aircraft models) In 1972 turboprops constituted a small percentage of certificated route air carrier operations but a more significant percentage of supplemental operations. The weighted percentages for each type of turboprop aircraft in AC use is carried through for 1974 and future years until turboprops are phased out of AC fleets at the selected airports as shown in the FAA Equipment Forecast.[12] Supplemental fleet airlines are replacing turboprops with turbojets as they become available. Although present predictions by the FAA indicate the phase out of AC turboprops, new turboprop aircraft for AC use may be developed to take advantage of potentially superior fuel economy.

Piston: (includes all piston engine aircraft models) No AC aircraft are found in this category for ORD, LAX, or JFK, therefore no estimations or further determinations are formulated.

Helicopter: (includes all helicopter models) These aircraft are excluded from this study as noted above.

Tables I-30, I-31 and I-32 summarize the estimated AC LTOs for 1975, 1980 and 1985 at the selected airports.

Table I-30

1975 Air Carrier LTOs for Selected Airports

Aircraft Type	(Engines)	JFK	LAX	ORD
BAC111-200 -400	(2RR-Spey-MK511)	5457	0	567
B727-100	(3JT3D)	22330	20130	59700
B727-200 (STR)		15950	42090	53730
DC-10-10	(3CF6-6D)	6007	17984	15560
DC-10-20	(3JT9D)	0	0	5674
DC-10-30	(3CF6-50)	1449	1396	258
B707-100B -300B -300C DC-8-50/62 B720B	(4JT3D)	38866	37859	27193
DC-8-10/20/30 B707-300	(4JT4A)	8187	5309	5662
DC-8-61/63	(4JT3D)	4785	3660	8955
B747	(4JT9D)	20735	12810	10448
DC-9-10/30	(2JT8D)	15211	8876	68088
B737-200		67	20405	
B720	(4JT3C)	385	1616	1225
L1011	(3RR-RB211)	6524	8071	5373
CV880	(4CF805-3B)	1460	586	7564
VC10	(4RR Conway)	1749	202	4
CV990	(4CJ805-23B)	393	198	138
F-27	(2RR-Dart 6-514)	0	856	1
L-100-30	(4 A11 501-D22A)	0	423	1090
L-188	(4 A11 501-D13)	0	551	923
Jetstar	(4TFE-731)	0	0	4
FH-227	(2RR Dart 7-532)	0	0	7788
DTO-6	(2PT6A-27)	0	0	3
CV580	(2 A11 501-D13)	0	0	17063

Table I-31

1980 Air Carrier LTOs for Selected Airports

Aircraft Type	(Engines)	JFK	LAX	ORD
BAC111	(2RR-Spey-MK511)	4775	0	0
VFW614	(2RR M45H)	682	0	567
B727-100	(3JT8D)	17750	8177	31501
B727-200	(3JT8D)	21833	50697	74456
B747	(4CF6-50)	4793	18706	15403
DC-10-10	(3CF6-6D)	9744	24708	24935
DC-10-10	(12.5% " Retro'd)	1392	3530	3562
DC-10-20(40)	(3JT9D)	610	0	9092
DC-10-20(40)	(12.5% " Retro'd)	87	0	1299
DC-10-30	(3CF6-50)	2350	1917	414
DC-10-30	(12.5% " Retro'd)	336	274	59
B707 B720B DC-8	(4JT3D Omnibuses)	39050	36486	29515
B747	(4JT9D)	24850	16971	14350
B747	(12.5% " Retro'd)	3550	2425	2050
DC9	(2JT8D)	22876	20537	97836
B737	(2JT8D)	67	20405	
L1011	(3RB-RB211)	10993	11088	8610
L1011	(12.5% " Retro'd)	1513	1584	1230
Jetstar	(4TFE731-3 Old)	0	0	5
VC10	(FR Conway)	0	145	0

Table I-32

1985 Air Carrier LTOs for Selected Airports

Aircraft Type	(Engines)	JFK	LAX	ORD
VFW614	(2RR M45H Old)	5985	0	1826
VFW614	(2RR M45H New)	5985	0	1825
B727-100	(3JT8D)	7980	2338	9321
B727-200	(3JT8D)	19950	39747	61521
B7X7	(3CFM56)	19950	37655	54368
DC-10-10	(3CF6-6D) (All Retro'd)	16694	36280	36261
DC-10-20(40)	(3JT9D) (All Retro'd)	1045	0	13222
DC-10-30	(3 CF6-50) (All Retro'd)	4027	2815	601
B707 B720B DC-8	(4JT3D Smokeless)	23940	17650	13178
B747	(4JT9D Retro'd)	25552	18441	16881
B747	(4JT9D New)	14348	10355	9479
DC-9	(2JT8D Retro'd)	20970	18542	69872
DC-9	(2JT8D New)	2903	2567	9673
B737	(2JT8D Old)	67	18761	20776
L1011	(3RR RB211) (Retro'd & New)	18135	16281	12521
Jetstar	(4TFE731-3 Old)	0	0	1
VC10	(RR Conway)	0	70	0

Air Taxi (AT) and General Aviation (GA)

The same fleet mix is carried from 1972 to 1985 in these groupings except for some attrition such as the CV 580's being phased out before 1980. Helicopter percentages of LTOs are carried through in determining the LTOs of the other aircraft. The same fleet mix is assumed because:

1) The distances traversed by AT will be the same and the aircraft fleet extant is highly fuel efficient over these routes;

2) GA falls to a minor contribution at LAX and is neglible at ORD and JFK by 1980;

3) Large AT aircraft are likely to be used to accomodate increasing passenger loads, but no estimates of the expected effect have been obtained.

4) No other projection data has been obtained for the selected (AC) airports for GA and AT.

Tables I-33 and I-34 summarize the estimated GA engine LTO's for the selected AC airports.

Table I-33

1975 Estimated Engine LTO's for
General Aviation at Selected Commercial Airports

Engine Type	JFK	LAX	ORD
CF700	772	8754	4266
CF610	2195	12644	5996
JT12	0	0	4932
JT15D	447	0	2306
SPEY MK511	252	7173	0
TFE 731	479	7054	0
PT6A-27	2184	7125	7000
TPE 331	1716	0	0
VIPER 601	650	0	0
ALLISON 501-D13	101	0	0
DART 7-532	428	0	0
TCM TSIO-520	3900	4275	10500
TCM IO-520	938	238	0

Table I-34

1980 and 1985 Estimated Engine LTO's
for General Aviation at LAX

Engine Type	1980	1985
CF700	1659	184
CJ610	2396	266
SPEY MK511	1359	152
TFE731	1337	148
PT6A-27	1350	150
TCM TSIO-30	810	90
TCM IO-520	45	5

Tables I-35, I-36, and I-37 summarize the estimated AT LTO's at the selected airports.

Table I-35

1975 Estimated Air Taxi LTO's
for Selected Commercial Airports

Aircraft Type	JFK	LAX	ORD
DeHavilland Twin Otter	4759	16327	540
SB&H Sky Liner	--	1745	--
Convair 580	--	510	--
Beechcraft 99	1984	--	11337
Swearingen Metro	--	--	14396
Cessna 402	--	--	1708
Piper Navaho	1194	--	--
General Prop A/C	217	--	2519
Helicopter	7346	9418	--

Table I-36

1980 Estimated Air Taxi LTO's
for Selected Commercial Airports

Aircraft Type	JFK	LAX	ORD
DeHavilland Twin Otter	5373	21380	699
SB&H Skyliner	--	2286	--
Convair 580	--	--	--
Beechcraft 99	2240	--	14682
Swearingen Metro	--	--	18644
Cessna 402	--	--	2212
Piper Navaho	1593	--	--
General Prop A/C	--	--	3263
Helicopter	8294	12334	--

Table I-37

1985 Estimated Air Taxi LTO's
for Selected Commercial Airports

Aircraft Type	JFK	LAX	ORD
DeHavilland Twin Otter	6140	28507	929
SB&H Skyliner	--	3048	--
Convair 580	--	--	--
Beechcraft 99	2560	--	19514
Swearingen Metro	--	--	24780
Cessna 402	--	--	2940
Piper Navaho	1820	--	--
General Prop A/C	--	--	4330
Helicopter	9480	16445	--

Tables I-38, I-39, and I-40 summarize estimated auxiliary power unit emissions at the selected aiports. APU's meeting 1979 standards are not assumed installed in aircraft with retrofitted engines in 1980.

Table I-38

1975 Estimated Auxiliary Power Unit
Use (LTO's) at Selected Commercial Airports

Aircraft	APU	JFK	LAX	ORD
BAC111	GTCP85-115	5457	--	567
B727	GTCP85-98	38280	62220	113430
DC-10	TSCP700-4	7456	19380	21492
B747	GTCP660-4	20735	12810	10448
DC-9	GTCP85-98	15211	8876	47312
L1011	ST6C	6524	8071	5373
B737	GTCP85-129	67	20405	20776
L188	GTC85-90*	--	551	923

*GTCP85-98 Data

Table I-39

1980 Estimated Auxiliary Power Unit
Use (LTO's) at Selected Commercial Airports

Aircraft	APU	JFK	LAX	ORD
BAC111(VFW614)	GTCP85-115(-98*)	5457	--	567
B727	GTCP85-98	39583	58875	105957
DC-10	TSCP700-4	14519	30429	39360
B747	GTCP660-4	28400	19395	16400
DC-9	GTCP85-98	22876	20537	77061
L1011	ST6C	12106	12672	9840
B737	GTCP85-129	67	20405	20776
B7X7	GTCP85-98*	4793	18706	15403

*New (>1979)

Table I-40

1985 Estimated Auxiliary Power Unit
Use (LTO's) at Selected Commercial Airports

Aircraft	APU	JFK	LAX	ORD
VFW614 (N)	GTCP85-98	11970	--	3652
B727 (O)	GTCP85-98	27930	42085	70843
DC-10 (O)	TSCP700-4	14519	36280	39360
DC-10 (N)	TSCP700-4	7247	2815	10724
B747 (O)	GTCP660-4	25552	18441	16881
B747 (N)	GTCP660-4	14348	10355	9479
DC-9 (O)	GTCP85-98	20970	18527	69872
DC-9 (N)	GTCP85-98	2903	2567	9673
L1011 (O)	ST6C	12106	11426	9840
L1011 (N)	ST6C	6029	4855	2681
B737 (O)	GTCP85-129	67	18761	21776
B7X7 (N)	GTCP85-98	19950	37655	54368

(O) < 1979
(N) > 1979

The estimated AC emissions are broken down in detail for each of the selected airports in Tables for 1975, 1980 and 1985. Tables I-41, I-42, and I-43 summarize JFK; Tables I-44, I-45, and I-46 summarize LAX; and Tables I-47, I-48, and I-49 summarize ORD.

Table I-41

1975 Estimated Air Carrier Emissions for JFK

Aircraft Type	HC	CO	NOx
BAC111	375,442	375,442	92,769
B727	769,428	3,227,004	1,251,756
DC-10-10	382,045	883,029	374,837
-20(40)	0	0	0
-30	98,242	248,648	140,843
B707 B720B DC-8	13,364,535	15,531,829	1,365,264
B747	2,073,500	5,921,916	2,189,616
DC-9 B737	204,725	858,624	333,060
B720	38,500	84,392	9,548
L1011	412,969	1,143,005	387,526
CV880	83,512	217,248	35,040
CV990	21,536	56,120	9,118
VC9 VC10	339,306	477,827	92,347

Table I-42

1980 Estimated Air Carrier Emissions for JFK

Aircraft Type		HC	CO	NOx
VFW614	(O)	67,805	342,845	22,252
	(N)	1,719	10,094	3,178
B727	(S)	795,618	3,336,847	1,294,364
B7X7	(N)	17,111	145,228	89,150
DC-10-10	(O)	619,718	1,432,368	608,026
-10	(R)	13,447	71,827	45,701
-20(40)	(O)	45,750	130,662	43,013
-20	(R)	1,122	6,055	3,732
-30	(O)	159,330	403,260	228,420
-30	(R)	3,871	20,765	12,499
B707 B720B DC-8	(S)	5,373,280	7,575,700	1,462,032
B747	(O)	2,485,000	7,097,160	2,624,160
	(R)	61,060	329,440	203,060
DC-9 B737	(S)	307,436	1,289,397	500,157
L1011	(O)	670,537	1,855,894	629,224
	(R)	12,845	68,993	41,759

(O) < 1979
(N) > 1979
(R) Retrofitted > 1979
(S) Smokeless (JT8D, JT3D)

Table I-43

1985 Estimated Air Carrier Emissions for JFK

Aircraft Type		HC	CO	NOx
VFW 614	(O)	84,987	429,723	27,890
	(N)	15,082	88,578	27,890
B727	(S)	561,393	2,354,499	913,311
B7X7	(N)	71,222	604,485	371,070
DC-10-10	(R)	161,264	861,410	515,845
-20(40)	(R)	13,481	72,732	44,831
-30	(R)	46,391	248,869	149,804
B707 B720B DC-8	(S)	3,294,144	4,644,360	896,314
B747	(R)	439,494	2,371,226	1,461,574
	(N)	253,673	1,377,408	826,445
DC-9	(S)	280,998	1,178,514	457,146
	(N)	9,232	49,351	30,772
B737	(S)	898	3,765	1,461
L1011	(R)	153,966	826,956	500,526

(O) < 1979
(N) > 1979
(R) Retrofitted > 1979
(S) Smokeless (JT8D, JT3D)

Table I-44

1975 Estimated Air Carrier Emissions for LAX

Aircraft Type	HC	CO	NOx
B727	853,036	3,682,602	1,907,665
DC-10-10	773,672	1,802,537	108,356
-30	64,179	163,692	132,838
B707 B720B DC-8	8,110,153	9,735,825	1,149.197
B747	872,617	2,509,735	1,279,975
DC-9 B737	267,619	1,155,389	598,483
B720	110,341	245,762	36,845
L1011	358,573	1,051,021	473,335
CV880	22,800	62,251	13,467
CV990	7,355	20,124	4,345
VC10	26,550	38,350	10,051
F27	2,602	2,517	1,952
L-100	4,670	4,518	3,502
L-188	5,775	13,026	4,893

Table I-45

1980 Estimated Air Carrier Emissions for LAX

Aircraft Type		HC	CO	NOx
B727	(S)	807,170	3,484,782	1,805,092
B7X7	(N)	46,521	412,120	324,859
DC-10-10	(O)	1,062,938	2,476,483	1,488,410
	(R)	23,083	132,462	105,038
DC-10-30	(O)	88,163	224,864	182,479
	(R)	2,146	11,558	9,692
B707 B720B DC-8	(S)	3,410,712	4,924,151	1,290,145
B747	(O)	1,156,031	3,324,861	1,695,693
	(R)	28,803	154,198	126,268
DC-9 B737	(S)	374,205	1,615,552	836,845
L1011	(O)	492,618	1,443,925	650,282
	(R)	9,371	50,485	41,927
VC10	(O)	19,040	27,501	7,208

(O) < 1979
(N) > 1979
(R) Retrofitted > 1979
(S) Smokeless (JT8D, JT3L)

Table I-46

1985 Estimated Air Carrier Emissions for LAX

Aircraft Type		HC	CO	NOx
B727	(S)	576,986	2,491,011	1,290,326
B7X7	(N)	93,648	829,615	653,955
DC-10-10	(R)	237,271	1,278,870	1,079,693
-30	(R)	22,042	118,737	99,567
B707 B720B DC-8	(S)	1,649,876	2,381,977	624,087
B747	(R)	219,073	1,172,816	960,381
	(N)	127,154	681,326	547,132
DC-9	(S)	169,474	731,668	378,999
	(N)	5,689	30,958	24,751
B737	(S)	171,476	740,309	383,475
L1011	(R)	96,316	518,892	430,929
VC10	(O)	9,223	13,323	3,492

(O) < 1979
(N) > 1979
(R) Retrofitted > 1979
(S) Smokeless (JT8D, JT3D)

Table I-47

1975 Estimated Air Carrier Emissions for ORD

Aircraft Type	HC	CO	NOx
BAC111	30,312	31,095	9,503
B727	1,766,105	7,564,647	3,545,822
DC-10-10	765,085	1,776,641	944,337
-20 (40)	330,738	948,466	432,359
-30	13,561	34,466	24,714
B707 B720B DC-8	8,315,230	9,850,344	1,049,665
B747	811,980	2,328,539	1,061,466
DC-9 B737	706,749	3,027,171	1,418,944
B720	95,266	210,859	28,605
L1011	268,865	772,262	316,255
CV880	335,842	900,721	176,393
CV990	5,862	15,754	3,080
C580	101,693	228,297	78,829
VC10	602	861	203
L-100	6,864	6,472	4,620
L-188	10,996	24,686	8,524
F27 F227 SD3	30,856	29,148	20,875
Jetstar	30	80	25

Table I-48

1980 Estimated Air Carrier Emissions for ORD

Aircraft Type		HC	CO	NOx
VFW614	(O)	6,362	32,774	2,506
B727	(S)	1,649,751	7,066,273	3,312,216
B7X7	(N)	43,899	785,091	378,452
DC-10-10	(O)	1,226,030	2,847,021	1,513,275
	(R)	26,609	143,086	107,181
-20(40)	(O)	529,973	1,519,819	692,811
	(R)	13,133	70,536	52,181
-30	(O)	21,734	55,240	39,609
	(R)	528	2,836	2,117
B707 B720B DC-8	(S)	3,150,968	4,505,094	1,062,286
B747	(O)	1,115,282	3,198,328	1,457,960
	(R)	27,634	148,420	109,798
DC9 B737	(S)	1,015,538	4,349,790	2,038,902
L1011	(O)	430,845	1,237,516	506,785
	(R)	8,222	44,266	32,959
Jetstar	(R)	34	90	28

(O) < 1979
(N) > 1979
(R) Retrofitted > 1979
(S) Smokeless (JT8D, JT3D)

Table I-49

1985 Estimated Air Carrier Emissions for ORD

Aircraft Type		HC	CO	NOx
VFW614	(O)	10,244	52,772	4,036
	(N)	1,836	10,848	4,041
B727	(S)	1,103,018	4,724,487	2,214,537
B7X7	(N)	153,316	1,330,916	965,567
DC-10-10	(R)	270,870	1,456,605	1,091,094
-10(40)	(R)	133,675	717,955	531,128
-30	(R)	5,373	28,884	21,564
B707 B720B DC-8	(S)	1,406,884	2,011,490	474,303
B747	(R)	227,556	1,222,185	904,147
	(N)	131,569	709,029	514,141
DC-9	(S)	725,272	3,106,509	1,456,133
	(N)	24,220	130,966	96,029
B737	(S)	215,650	923,679	432,962
L1011	(R)	83,691	450,606	335,513
Jetstar	(N)	4	10	3

(O) < 1979
(N) > 1979
(r) Retrofitted > 1979
(S) Smokeless (JT8D, JT3D)

Tables I-50, I-51, and I-52 summarize AT, GA and APU emissions at JFK for 1975, 1980 and 1985; Tables I-53, I-54 and I-55 summarize AT, GA and APU emissions at LAX; and, Tables I-56, I-57 and I-58 summarize AT, GA and APU emissions at ORD.

Table I-50

Estimated Air Taxi Emissions for JFK

Aircraft Type	HC	CO	NOx
1975			
Beechcraft 99	10,317	7,341	1,389
DeHavilland Twin Otter	24,747	35,217	3,331
Piper Navaho	3,810	64,059	310
1980			
Beechcraft 99	11,648	16,576	1,568
DeHavilland Twin Otter	27,940	39,760	3,762
Piper Navaho	4,301	72,322	350
1985			
Beechcraft 99	9,984	14,208	1,344
Beechcraft 99 (N)	550	2,982	845
DeHavilland Twin Otter	23,946	34,077	3,224
DeHavilland Twin Otter (N)	1,320	7,153	2,026
Piper Navaho	4,914	82,628	400

(N) 25% New Aircraft that meet 1979 Standards

Table I-51

Estimated General Aviation Emissions for JFK

Engine Type	HC	CO	NOx
1975			
Dart 7-532	1113	984	599
Allison 501-D13	384	859	253
Spey 511	8669	8669	2142
TFE 731-2	1150	2970	766
JT15D	1743	4559	492
CJ610	10975	111945	1800
CF700	3397	33968	718
Viper 601	2860	28600	605
TPE331	8752	6864	1098
PT6A-27	5678	8081	764
TCM TSIO-520	5265	88530	429
TCM IO-520	1097	25138	64
1980 & 1985			

General Aviation operations assumed negligible.

Table I-52

Estimated Auxiliary Power Unit Emissions for JFK

Aircraft	Type	HC	CO	NOx
1975				
BAC111	(O)	65	10,405	11,940
B727	(O)	2,552	97,333	88,299
DC-10	(O)	1,939	9,854	73,342
B747	(O)	14,929	590,948	363,277
DC-9	(O)	1,014	38,677	35,087
L1011	(O)	7,209	39,296	56,541
B737	(O)	5	211	135
1980				
VFW614	(N)	291	10,186	6,112
B727	(O)	2,639	100,646	91,305
DC-10	(O)	3,775	19,189	142,819
B747	(O)	20,448	809,400	497,568
DC-9	(O)	1,525	58,166	52,767
L1011	(O)	13,377	72,918	104,919
B737	(O)	5	211	135
B7X7	(N)	256	8,947	5,368
1985				
VFW614	(N)	638	22,344	13,406
B727	(O)	1,862	71,017	64,425
DC10	(O)	3,775	19,189	142,819
DC10	(N)	1,413	8,636	35,329
B747	(O)	18,397	728,232	447,671
B747	(N)	8,609	258,264	154,958
DC9	(O)	1,398	53,320	48,371
DC9	(N)	155	5,419	3,251
L1011	(O)	13,377	72,918	104,919
L1011	(N)	1,306	7,838	32,135
B737	(O)	5	211	135
B7X7	(N)	1,064	37,240	22,344

(O) < 1979
(N) > 1979

Table I-53

Estimated Air Taxi Emissions for LAX

Aircraft Type	HC	CO	NOx
1975			
DeHavilland Twin Otter	58,124	84,900	9,992
SB&H Skyliner	11,932	13,747	2,034
CV580	2,670	6,022	2,262
1980			
DeHavilland Twin Otter	76,113	111,176	13,085
SB&H Skyliner	15,636	18,014	2,665
1985			
DeHavilland Twin Otter	76,113	111,176	13,085
DeHavilland Twin Otter (N)	4,305	23,519	7,811
SB&H Skyliner	15,636	18,014	2,665
SB&H Skyliner (N)	453	2,527	888

(N) 25% New aircraft that meet 1979 standards.

Table I-54

Estimated General Aviation Emissions for LAX

Engine Type	HC	CO	NOx
1975			
CJ610	43,495	480,725	9,458
Spey 511	168,004	175,069	59,800
TFE731	11,498	31,249	10,863
CF700	26,350	281,266	7,485
PT6A-27	12,683	18,525	2,180
TCM TSIO-520	4,157	82,337	457
TCM IO-520	202	5,805	15
1980			
CJ610	8,242	91,096	1,792
Spey 511	31,835	33,173	11,332
TFE731	2,180	5,923	2,059
CF700	4,994	53,304	1,419
PT6A-27	2,403	3,510	413
TCM TSIO-520	788	15,601	87
TCM IO-520	38	1,098	3
1985			
CJ610	915	10,052	199
Spey 511	3,561	3,710	1,267
TFE731	241	656	228
CF700	554	5,912	157
PT6A-27	267	390	46
TCM TSIO-520	88	1,733	10
TCM IO-520	4	122	0

Table I-55

Estimated Auxiliary Power Unit Emissions for LAX

Aircraft	Type	HC	CO	NOx
1975				
B727	(O)	4,148	158,205	143,521
DC-10	(O)	5,039	25,613	190,630
B747	(O)	9,223	365,085	224,431
DC-9	(O)	592	22,568	20,473
L1011	(O)	8,918	48,612	69,945
B737	(O)	1,497	64,288	41,245
L188	(O)	37	1,401	1,271
1980				
B727	(O)	3,925	149,698	135,804
DC-10	(O)	7,912	40,217	299,315
B747	(O)	13,965	552,758	339,801
DC-9	(O)	1,369	52,219	47,372
L0100	(O)	14,002	76,325	109,820
B737	(O)	1,497	64,288	41,245
7X7	(N)	998	34,917	20,950
1985				
B727	(O)	2,806	107,008	97,076
DC-10	(O)	9,433	47,950	356,875
DC-10	(N)	549	3,355	13,723
B747	(O)	13,277	525,555	323,078
B747	(N)	6,213	186,381	111,829
DC-9	(O)	1,236	47,146	42,770
DC-9	(N)	137	4,792	2,875
L1011	(O)	12,625	68,820	99,021
L1011	(N)	1,052	6,312	25,877
B737	(O)	1,376	59,110	37,922
7X7	(N)	2,009	70,290	42,174

(O) < 1979
(N) > 1979

Table I-56

Estimated Air Taxi Emissions for ORD

Aircraft Type	HC	CO	NOx
1975			
Beechcraft 99	46,029	66,208	7,211
Swearingen Metro	112,577	89,543	17,275
DeHavilland Twin Otter	2,192	3,154	343
Cessna 402	1,172	21,922	117
General Prop A/C	19,699	15,668	3,023
1980			
Beechcraft 99	59,609	85,743	9,337
Swearingen Metro	145,796	115,966	22,372
DeHavilland Twin Otter	2,838	4,082	445
Cessna 402	4,789	89,595	477
General Prop A/C	25,517	20,296	3,916
1985			
Beechcraft 99	59,609	85,743	9,337
Beechcraft 99 (N)	3,284	17,878	5,624
Swearingen Metro	145,796	115,959	22,371
Swearingen Metro (N)	4,172	23,094	7,363
DeHavilland Twin Otter	2,838	4,082	445
DeHavilland Twin Otter (N)	156	851	268
Cessna 402	4,210	78,756	419
General Prop A/C	25,517	20,303	3,917
General Prop A/C (N)	731	4,044	1,289

(N) 25% new aircraft that meet 1979 standards.

Table I-57

Estimated General Aviation Emissions for ORD

Engine Type	HC	CO	NOx
1975			
CF700	14,590	152,254	3,737
CJ610	23,396	251,652	4,623
JT12	19,245	206,996	3,803
JT15D	7,056	18,736	2,306
PT6A-27	14,210	20,440	2,226
TCM TSIO-520	11,393	213,129	1,134
1980 & 1985			

General aviation operations assumed neglible.

Table I-58

Estimated Auxiliary Power Unit Emissions for ORD

Aircraft Type		HC	CO	NOx
1975				
BAC111	(O)	7	1,081	1,241
B727	(O)	7,562	288,415	261,645
DC-10	(O)	5,588	28,406	211,410
B747	(O)	7,522	297,754	183,040
DC-9	(O)	3,154	120,300	109,134
L1011	(O)	5,937	32,364	46,566
B737	(O)	1,524	65,457	41,994
L188	(O)	62	2,346	2,128
1980				
BAC111	(O)	7	1,081	1,241
B727	(O)	7,064	269,414	244,408
DC-10	(O)	10,234	52,021	387,171
B747	(O)	11,808	467,400	287,328
DC-9	(O)	5,138	195,939	177,753
L1011	(O)	10,873	59,270	85,280
B737	(O)	1,524	65,457	41,994
B7X7	(N)	822	28,753	17,252
1985				
VFW614	(N)	22	3,481	3,994
B727	(O)	4,723	180,129	163,410
DC-10	(O)	10,234	52,021	387,171
DC-10	(N)	2,091	12,780	52,280
B747	(O)	12,155	481,109	295,755
B747	(N)	5,688	170,622	102,373
DC-9	(O)	4,658	177,661	161,171
DC-9	(N)	516	18,056	10,833
L1011	(O)	10,873	59,270	85,280
L1011	(N)	581	3,486	14,290
B737	(O)	1,524	64,457	41,994
B7X7	(N)	2,900	101,486	60,892

(O) < 1979
(N) > 1979

The total summations for AC, AT, GA and APU for each year studied are combined to produce Tables 1, 2, 3 and 4 in the discussion section of this study above and Tables I-59 through I-61 as follows:

Table I - 59
Estimated Total Aircraft Emissions at JFK

	CY 1972						FY 1975					
lbs/yr x 10^{-3}	HC	%	CO	%	NOx	%	HC	%	CO	%	NOx	%
AC	21,117	99.35	30,233	96.26	5,686	91.90	18,164	99.35	29,025	95.98	6,282	90.70
AT	36	0.17	104	0.33	5	0.08	39	0.22	107	0.36	5	0.07
GA	82	0.39	413	1.32	20	0.32	51	0.28	321	1.06	10	0.15
APU	19	0.09	657	2.09	476	7.70	28	0.15	787	2.60	629	9.08
Total x 10^{-3} (lbs/yr)	21,254	100	31,407	100	6,187	100	18,282	100	30,240	100	6,926	100
÷ 2000 (T/yr)	10,627		15,704		3,094		9,141		15,120		3,463	
÷ 365 (T/DA)	29.1		43.0		8.5		25.0		41.4		9.5	
÷ 7.2 (T/dA/mi^2)	4.0		6.0		1.1		3.5		5.8		1.3	

	FY 1980						FY 1985					
lbs/yr x 10^{-3}	HC	%	CO	%	NOx	%	HC	%	CO	%	NOx	%
AC	10,643	99.20	24,159	95.23	7,825	89.61	5,390	98.30	15,131	91.39	6,237	85.26
AT	44	0.41	129	0.51	6	0.07	41	0.75	141	0.85	8	0.11
GA	-	-	-	-	-	-	-	-	-	-	-	-
APU	42	0.39	1,080	4.26	901	10.32	52	0.95	1,285	7.76	1,070	14.63
Total x 10^{-3} (lbs/yr)	10,729	100	25,368	100	8,732	100	5,483	100	16,557	100	7,315	100
÷ 2000 (T/yr)	5,365		12,684		4,366		2,742		8,279		3,658	
÷ 365 (T/DA)	14.7		34.8		12.0		7.5		22.7		10.0	
÷ 7.2 (T/DA/mi^2)	2.0		4.8		1.7		1.0		3.2		1.4	

Table I - 60
Estimated Total Aircraft Emissions at LAX

lbs/yr x 10^{-3}	CY 1972 HC	%	CO	%	NOx	%	FY 1975 HC	%	CO	%	NOx	%
AC	14,792	97.39	23,128	92.18	5,938	90.84	11,478	96.89	20,485	91.65	6,698	89.38
AT	65	0.43	94	0.37	13	0.20	73	0.62	105	0.47	14	0.18
GA	314	2.07	1,269	5.06	107	1.63	266	2.25	1,075	4.81	90	1.20
APU	17	0.11	600	2.39	479	7.33	29	0.24	686	3.07	692	9.23
Total x 10^{-3} (lbs/yr)	15,188	100	25,091	100	6,537	100	11,846	100	22,351	100	7,494	100
÷ 2000 (T/yr)	7,594		12,546		3,269		5,923		11,176		3,747	
÷ 365 (T/DA)	20.8		34.4		9.0		16.2		30.6		10.3	
÷ 3.9	5.3		8.8		2.3		4.2		7.9		2.6	

lbs/yr x 10^{-3}	FY 1980 HC	%	CO	%	NOx	%	FY 1985 HC	%	CO	%	NOx	%
AC	7,521	97.59	18,283	93.35	8,564	89.29	3,378	95.64	10,990	89.39	6,477	84.60
AT	92	1.19	129	0.66	16	0.17	97	2.75	155	1.26	24	0.31
GA	50	0.65	204	1.04	17	0.18	6	0.17	23	0.18	2	0.03
APU	44	0.57	970	4.95	994	10.36	51	1.44	1,127	9.17	1,153	15.06
Total x 10^{-3} (lbs/yr)	7,707	100	19,586	100	9,591	100	3,532	100	12,295	100	7,656	100
÷ 2000 (T/yr)	3,854		9,793		4,796		1,766		6,148		3,828	
÷ 365 (T/DA)	10.6		26.8		13.1		4.8		16.8		10.5	
÷ 3.9 / ($T/DA/mi^2$)	2.7		6.9		3.4		1.2		4.3		2.7	

Table I - 61
Estimated Total Aircraft Emissions at ORD

lbs/yr x 10^{-3}	CY 1972 HC	%	CO	%	NOx	%	FY 1975 HC	%	CO	%	NOx	%
AC	17,397	98.59	30,163	94.09	8,012	92.19	13,597	97.82	27,751	93.61	9,124	90.99
AT	137	0.78	181	0.56	21	0.24	182	1.31	196	0.66	28	0.28
GA	90	0.51	988	3.08	20	0.23	90	0.65	863	2.91	18	0.18
APU	21	0.12	727	2.27	638	7.34	31	0.22	836	2.82	857	8.55
Total x 10^{-3} (lbs/yr)	17,645	100	32,059	100	8,691	100	13,900	100	29,646	100	10,027	100
÷ 2000 (T/yr)	8,823		16,030		4,346		6,950		14,823		5,014	
÷ 365 (T/DA)	24.2		43.9		11.9		19.0		40.6		13.7	
÷ 6.7 (T/DA/mi^2)	3.6		6.6		1.8		2.8		6.1		2.1	

lbs/yr x 10^{-3}	FY 1980 HC	%	CO	%	NOx	%	FY 1985 HC	%	CO	%	NOx	%
AC	9,267	97.01	26,006	94.70	11,309	89.84	4,493	93.70	16,877	90.96	9,045	86.35
AT	239	2.50	316	1.15	37	0.29	246	5.13	351	1.89	51	0.49
GA	-	-	-	-	-	-	-	-	-	-	-	-
APU	47	0.49	1,139	4.15	1,242	9.87	56	1.17	1,326	7.15	1,379	13.16
Total x 10^{-3} (lbs/yr)	9,553	100	27,461	100	12,588	100	4,795	100	18,554	100	10,475	100
÷ 2000 (T/yr)	4,777		13,731		6,294		2,398		9,277		5,238	
÷ 365 (T/DA)	13.1		37.6		17.2		6.6		25.4		14.3	
÷ 6.7 (T/DA/mi^2)	2.0		5.6		2.6		1.0		3.8		2.1	

PART II

Methodology for Computation of Aircraft Emissions at Airports with High Levels of General Aviation Operations

Table II-1 lists the predominantly general aviation (GA) activity airports selected for estimation of GA emissions and their significance to the surrounding communities.

Table II-1

General Aviation (GA) Airports Selected for Study[27]

Airport	Code	Total Operations %GA	U.S. Rank
Van Nuys	(VNY)	99.4	3
Tamiami	(TMB)	99.6	31
Phoenix	(PHX)	74.8	9
Fairbanks	(FAI)	70.9	133
San Jose Municipal	(SJC)	91.7	10
San Jose Reid Hillview	(RHV)		28

Both San Jose airports are located within the city limit of San Jose and are combined to provide a city wide sample. Van Nuys has the largest total number of GA operations in the U.S. in 1974 and is located in the Los Angeles basin. Phoenix and Tamiami are selected for high GA usage in urban areas with hot sunny climates. Fairbanks is selected as a small community with extremely high GA activity for the community size and severe temperature inversions. Table II-2 presents the breakdown of operations for the above airports in detail, the data being obtained from the FAA Air Traffic Activity for CY 1974, Table 4.[27]

Table II-2

CY1974 Total Operations for Selected GA Airports

Operations	SJC&RHV	PHX	VNY	TMB	FAI
Total	718,100	417,998	586,680	290,147	166,029
Military	1,462 (0.02%)	10,064 (2.4%)	3,627 (0.6%)	1,168 (0.4%)	2,051 (1.2%)
GA & Local	658,207 (91.7%)	312,682 (74.8%)	582,959 (99.4%)	288,979 (99.6%)	117,738 (70.9%)
AT	8,227 (1.15%)	9,010 (2.2%)	85 (0.001%)	0	30,174 (18.2%)
AC	50,204 (6.99%)	86,242 (20.6%)	9 (0.001%)	0	16,066 (9.7%)

The number of active GA aircraft in each U.S. county is listed in Table 23 of the FAA Census of U.S. Civil Aircraft for CY1973 and is broken down according to number and type of engines.[13] Table II-3 presents the percentages of each type of GA aircraft according to number and type of engine for each of the above selected airports. The percentage breakdown of GA aircraft operations at each airport selected is assumed to be the same as the percentage breakdown of active GA aircraft in the surrounding county. This assumption appears reasonable for airports that are substantially devoted to GA activity. Applying these percentages to the GA and local operations from Table II-2 and dividing by two, the number of LTOs for each type of aircraft are obtained and shown in Table II-4.

Table II-3

CY1973 Percent Active GA Aircraft by Engine Type and Number for Selected GA Airports

Engine Number	Type	SJC&RHV	PHX	VNY	TMB	FAI
Single	Piston	88.1	80.6	80.4	66.8	92.3
Twin	Piston	9.4	12.0	11.2	24.6	3.9
3 +	Turboprop	0.08	0.7	0.2	2.3	0.7
Single	Turboprop	0	0.2	0	0	0.4
Twin	Turboprop	0.3	0.7	0.9	1.6	0
4 +	Turboprop	0	0.1	0.09	0.7	0.3
Single	Turbojet	0	0	0.07	0.1	0
Twin	Turbojet	0.3	0.3	0.8	0.6	0
3 +	Turbojet	0	0	0.2	0.6	0
Rotorcraft		1.7	5.5	6.1	2.8	2.4

Table II-4

CY1974 Number of GA Aircraft LTOs by Engine Type and Number for Selected GA Airports

Engine Number	Type	SJC&RHV	PHX	VNY	TMB	FAI
Single	Piston	289,940	126,011	234,350	96,519	54,336
Twin	Piston	30,936	18,761	32,646	35,544	2,296
3 +	Piston	263	1,094	583	3,323	412
Single	Turboprop	0	313	0	0	0
Twin	Turboprop	987	1,094	2,624	2,312	0
4 +	Turboprop	0	156	263	1,011	117
Single	Turbojet	0	0	204	144	0
Twin	Turbojet	987	469	2,332	867	0
3 +	Turbojet	0	0	583	867	0
Rotorcraft		5,595	8,599	17,897	4,046	1,413

Tables II-3 and II-4 demonstrate that the overwhelming majority of GA operations are performed by single and twin engine piston aircraft. Table II-5 lists HP and baseline emissions in pounds per LTO for eight piston engines. Table II-5 is derived from baseline emission factors supplied by the respective engine manufacturers.[28,29,30]

Table II-5

Baseline Engine Emission Factors in
Pounds per LTO for Selected Piston Engines

Man.	Engine Mod.	HP	HC	CO	NOx
TCM+	TSIO-360-C	225	1.0575	21.825	1.0315
LYC*	IO-320-D	160	0.192	10.56	0.0288
LYC	IO-360-B	180	0.288	12.24	0.0504
LYC	O-320-D	160	0.255	16.00	0.0624
TCM	O-200-A	100	0.22	8.9	0.05
TCM	IO-520-D	300	0.66	23.7	0.072
TCM	Tiara G-285-B	285	0.399	21.66	0.1197
TCM	GTSIO-520-K	435	0.609	37.845	0.0957

+TCM = Teledyne Continental Motors
*LYC = Avco Lycoming

The LTO is that currently specified in the Federal Register at 38 FR 19101 for P1 class engines.

To further break down the single and twin engine piston aircraft, the percentage distribution of GA aircraft by manufacturer and model utilizing each selected GA airport is assumed to coincide with the overall distribution nationwide. Table 25 of the 1973 U.S. Census of Civil Aircraft lists the active GA piston aircraft by manufacturer and number.[13] The corresponding engine manufacturer, horsepower and number of engines is listed. Only those single engine models with more than 1000 active aircraft and twin engine models with more than 100 active aircraft are included in the study to reduce the complexity of the analysis. Such single engine models comprise 84% of the total single engine active national population and 90% of the total twin engine active national population.

For those aircraft that do not utilize any of the engines listed in Table II-5, an engine of similar horsepower is selected from Table II-5 and assumed. Thus, a nationwide percentage distribution of the eight engines for single engine aircraft and for twin engine aircraft is obtained and listed in Tables II-6 and II-7. The Pratt and Whitney radial engine used on the DC-3 is assumed to be equivalent to 3 GTS IO-520-K engines.

Table II-6

National Engine Distribution:
Single Piston Engine Aircraft

Man.	Engine Mod.	Number of Engines	% of Total
TCM	TSIO-360-C	2,918	2.9
LYC	IO-320-D	7,219	7.1
LYC	IO-360-B	19,257	19.0
LYC	O-320-D	7,944	7.9
TCM	O-200-A	37,146	36.7
TCM	IO-520-D	4,910	4.9
TCM	Tiara G-285-B	18,376	18.2
TCM	GTSIO-520-K	3,342	3.3

Table II-7

National Engine Distribution:
Twin Piston Engine Aircraft

Man.	Engine Mod.	Number of Engines	% of Total
TCM	TSIO-360-C	1,790	6.1
LYC	IO-360-B	1,510	5.2
LYC	O-320-D	7,876	27.0
TCM	IO-520-D	11,962	41.0
TCM	GTSIO-520-K	6,050	20.7

The percentages in Tables II-6 and II-7 are applied to the single and twin piston engine numbers of LTOs from Table II-4 taking care to multiply by two for the twin engine LTOs. The resulting numbers of LTOs per engine per selected airport per year are multiplied by the respective pollutant emissions per LTO from Table II-5, summed and divided by 2000 to obtain Table II-8 and Table 5 above in the discussion section for the selected GA airports. The percentages of total LTOs are the sum of the single and twin engine piston percentages for GA multiplied by the percent GA and local from Table II-2. Note that Phoenix includes the piston engine AT (Cessna 402) and that Fairbanks includes all AT as twin engine piston with the same engine distribution assumed as the GA twin engine piston.[10]

Table II-8

CY1974 Summary of Total Emissions from GA Aircraft at Selected Airports in T/Yr

Airport	% of Total LTOs	HC	CO	NOx
Van Nuys (VNY)	91.6	56	2488	10
Tamiami (TMB)	91.0	35	1551	6
Phoenix (PHX)*	71.0	33	1448	6
Fairbanks (FAI)+	86.4	14	631	3
San Jose Municipal(SJC) San Jose Reid HV (RHV)	89.4	64	2827	12

*Includes piston engine AT

+Includes all AT as twin piston engine

The current trend toward twin engine piston, twin engine turboprop and twin engine turbojet for business and executive flying is expected to continue. Single engine piston will continue to predominate for pleasure flying. With the exception of rotorcraft all the GA categories

except single and twin engine piston were negligible in CY1974 (see Tables II-3 and II-4). Rotorcraft are not included in this study. Therefore, for purposes of estimating pollutant emissions in 1980 the calculations are based largely upon single and twin engine piston operations. The engine distributions within the single and twin engine categories are assumed unchanged. Baseline emissions are assumed to present a worst case situation.

Table II-9 for FY1980 and Table II-10 for FY1985 are derived by interpolation from the Terminal Area Forecast for 1976-1986.[8] Military operations are assumed to remain constant in accordance with the FAA assumption for the Terminal Area Forecast. Based on the trends toward single and twin engine aircraft noted above, the percentages of active GA aircraft at each selected airport as assumed are listed in Tables II-11 and II-12 respectively for FY1980 and FY1985. Applying these percentages to Tables II-9 and II-10 and dividing by two, the predicted LTOs in Tables II-13 and II-14 are obtained. Note as above that Phoenix includes piston engine AT and that Fairbanks includes all AT as twin engine piston.

Table II-9

FY1980 Predicted Operations for Selected GA Airports

Operations	SJC&RHV	PHX	VNY	TMB	FAI
Total	951,000	544,000	783,000	446,000	242,000
Military	1,462 (0.15%)	10,064 (2%)	3,637 (0.5%)	1,168 (0.3%)	2,051 (0.8%)
GA & Local	878,538 (92.4%)	418,936 (77%)	778,363 (99.4%)	444,832 (99.7%)	189,949 (78.5%)
AT	10,000 91.1%)	10,000 (2%)	1,000 (0.1%)	0	33,000 (13.6%)
AC	61,000 (6.4%)	105,000 (19%)	0	0	17,000 (7.0%)

Table II-10

FY1985 Predicted Operations for Selected GA Airports

Operations	SJC&RHV	PHX	VNY	TMB	FAI
Total	1,068,000	611,000	879,000	634,000	304,000
Military	1,462 (0.1%)	10,064 (2%)	3,637 (0.4%)	1,168 (0.2%)	2,051 (0.7%)
GA & Local	983,538 (92.1%)	469,936 (77%)	874,363 (99.5%)	632,832 (99.8%)	241,949 (79.6%)
AT	14,000 (1.3%)	14,000 (2%)	1,000 (0.1%)	0	37,000 (12.2%)
AC	69,000 (6.5%)	117,000 (19%)	0	0	23,000 (7.6%)

Table II-11

FY1980 Predicted Percent Active GA Aircraft
by Engine Type and Number for Selected GA Airports

Engine Number	Type	SJC&RHV	PHX	VNY	TMB	FAI
Single	Piston	88	80	80.5	68	93
Twin	Piston	9	12.5	11	25	4
Twin	Turboprop	0.5	1	1	2	0
Twin	Turbojet	0.5	0.5	1	2	0
Rotorcraft		2	6	6.5	3	3

Table II-12

FY1985 Predicted Percent Active GA Aircraft
by Engine Type and Number for Selected GA Airports

Engine Number	Type	SJC&RHV	PHX	VNY	TMB	FAI
Single	Piston	88	80	80.5	68	93
Twin	Piston	9	12.5	11	25	4
Twin	Turboprop	0.5	1	1	2	0
Twin	Turbojet	0.5	0.5	1	2	0
Rotorcraft		2	6	6.5	3	3

Table II-13

FY1980 Predicted Number of GA Aircraft LTOs
by Engine Type and Number for Selected GA Airports

Engine Number	Type	SJC&RHV	PHX	VNY	TMB	FAI
Single	Piston	386,557	167,574	313,291	151,243	88,326
Twin	Piston	39,534	26,184	42,810	55,604	3,799
Twin	Turboprop	2,196	2,095	3,892	4,448	0
Twin	Turbojet	2,196	1,047	3,892	4,448	0
Rotorcraft		8,785	12,568	25,296	6,672	2,849

Table II-14

FY1985 Predicted Number of GA Aircraft LTOs
by Engine Type and Number for Selected GA Airports

Engine Number	Type	SJC&RHV	PHX	VNY	TMB	FAI
Single	Piston	432,757	187,974	351,931	215,163	112,506
Twin	Piston	44,259	29,371	48.090	79,104	4,839
Twin	Turboprop	2,459	2,350	4,372	6,328	0
Twin	Turbojet	2,459	1,175	4,372	6,328	0
Rotorcraft		9,835	14,098	28,417	9,492	3,629

As above, the percentages in Tables II-6 and II-7 are applied to the numbers of LTOs in Tables II-13 and II-14, multiplied by the respective pollutant emissions per LTO from Table II-5, summed and divided by 2000 to obtain Tables 6 and 7 in the discussion section of this study above.

References

1. An Air Pollution Impact Methodology for Airports - Phase I, January 1973; United States Environmental Protection Agency.

2. Airport Emission Inventory Methodology - Final Report; December 1974; GCA/Technology Division

3. The Impact of Aircraft Emissions Upon Ambient Air Quality - 1972; Northern Research and Engineering Corporation

4. Aircraft Emissions: Impact on Air Quality and Feasibility of Control - Undated; United States Environmental Protection Agency

5. Jet Aircraft Emissions and Air Quality in the Vicinity of the Los Angeles International Airport - April 1971; Air Pollution Control District, County of Los Angeles

6. Measurements of Air Pollutant Concentrations at O'Hare International Airport, Chicago and Orange County Airport, California - March 1972; Celesco Industries

7. Airport Vicinity Air Pollution Study - Final Report; December 1973; United States Department of Transportation

8. Terminal Area Forecast 1976-1986 - September 1974; United States Department of Transportation

9. Airport Activity Statistics of Certified Route Air Carriers for 1972; United States Department of Transportation

10. Official Airline Guide, North American Edition, August 1, 1975; Reuben H. Donnelly Corporation

11. FAA - Air Traffic Activity - 1972; United States Department of Transportation

12. Equipment Forecast for top 25 Air Carrier Airports 1975 - 2000; United States Department of Transportation.

13. Census of U.S. Civil Aircraft - Calendar Year 1973; United States Department of Transportation

14. Traffic Flow - December 1972; International Civil Aviation Organization

15. Non-Scheduled Air Transport - 1972; International Civil Aviation Organization, Publication #184

16. Fleet Mix Publication; The National Air Carrier Association, Washington, D.C.

17. General Aviation Activity Survey - 1972; Department of Transportation

18. Conversation with Tom Connel, Chief Dispatcher, Butler Aviation, O'Hare International Airport, July 31, 1975

19. Conversation with Joe Windisch of the New York Port Authority, May 27, 1976

20. Unpublished report from TWA, Eastern, American and United Airlines to Charles Gray, EPA on taxi-idle times at LAX, JFK, ORD, and DCA, July, 1971 (officially directed to Northern Research).

21. O'Hare Airport Emission Inventory, Argonne National Labs for FAA, Lawrence Wangen, July, 1973

22. Airport Activity Statistics of Certified Route Air Carriers for 1973; United States Department of Transportation

23. Official Airline Guide, International Edition - July 1975; Reuben H. Donnelly Corporation

24. Jane's All The World Aircraft - 1972

25. DMS Air World Survey, Supplement to Volume 27, No. 4, 1975

26. Communication from Bernard Hannan of the Federal Aviation Administration

27. FAA - Air Traffic Activity - 1974; United States Department of Transportation

28. Exhaust Emissions Survey of a Piston Aircraft Engine - AVCO-Lycoming Division; Undated

29. Teledyne Continental Motors - Written Communication at EPA meeting July 22, 1976

30. AVCO - Lycoming Division - Monthly Report, February 1976